ORIGINAL ARTICLE

Effectiveness of an augmented reality-based HI Bogi application in improving toothbrushing skills among elementary school children: a quasi-experimental study

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ABSTRACT

Introduction: Oral health is an essential component of overall quality of life; however, the prevalence of dental caries in Indonesia remains high, particularly among elementary school children, partly due to inadequate toothbrushing skills. Various digital educational innovations, including mobile health applications and augmented reality (AR)-based interventions, have demonstrated positive effects on oral health education and behavioral change. Nevertheless, evidence regarding the effectiveness of the HI Bogi AR-based application, especially in improving children's toothbrushing skills, remains limited. Therefore, this study aimed to analyze the effectiveness of the augmented reality-based HI Bogi application in improving toothbrushing skills among elementary school children using a quasi-experimental design. **Methods:** This study employed a quasi-experimental design with a one-group pre- *and post-test design*. A total of 170 elementary school students aged 9–12 years from Cimahi City were recruited using simple random sampling. The intervention involved the use of the HI Bogi AR-based application for 21 days. The research instrument was an observational questionnaire comprising 13 indicators of toothbrushing skills. Data were analyzed using a paired *t*-test for normally distributed data and the Wilcoxon signed-rank test for non-normal data. **Results:** Toothbrushing skills improved significantly following the intervention (Wilcoxon signed-rank test: $Z = -15.192$, $p < 0.001$). The mean toothbrushing skill score increased from 4.40 ± 3.77 at baseline to 12.62 ± 0.71 after the intervention, representing an average improvement of 8.22 points. These findings indicate that the HI Bogi AR application substantially improved children's toothbrushing skills. **Conclusion:** The HI Bogi application integrated with augmented reality (AR) proved effective in improving proper toothbrushing skills among children aged 9–12 years in Cimahi City. This innovation has the potential to serve as an alternative, promotive, and preventive oral health education tool to support school-based oral health programs.

KEYWORDS

Augmented Reality, HI Bogi, oral health education, toothbrushing skills, children, oral hygiene behaviour

INTRODUCTION

Oral health is an essential component of overall health and quality of life. Dental caries is the most prevalent chronic disease among children worldwide. The World Health Organization estimates that approximately 514 million children are affected by caries in the primary dentition globally. Despite continuous oral health promotion efforts, Indonesia continues to experience a high burden of childhood dental caries, with the 2023 National Health Survey (SKI 2023) reporting a prevalence of 82.8%. These findings underscore the urgent need for effective

preventive and educational interventions aimed at improving children's oral hygiene behaviors.[1]

Poor oral hygiene, particularly ineffective toothbrushing practices, is a major modifiable risk factor for dental caries.[2] Children aged 9–12 years represent a critical developmental period because they undergo significant cognitive and behavioral maturation.[3] During this stage, children develop improved logical thinking, greater independence, and enhanced capacity to understand, practice, and maintain health-related behaviors.[4] As lifelong oral hygiene habits are often established during late childhood, interventions implemented at this age have a greater likelihood of producing sustained behavioral changes.[5]

Nevertheless, a preliminary survey conducted by the authors in Cimahi revealed that only 56.6% of children demonstrated correct toothbrushing techniques, while 43.4% practiced improper Fones brushing methods. These findings highlight the need for innovative educational strategies that effectively engage children and facilitate the acquisition of appropriate toothbrushing skills.

Children aged 9–12 years are in a critical developmental stage, in which cognitive and behavioral patterns related to health are formed. Previous studies have shown that these interventions effectively improve children's oral health knowledge and awareness immediately after education. However, their impact on psychomotor toothbrushing skills, plaque reduction, and long-term adherence to appropriate oral hygiene practices has been inconsistent. Several systematic reviews have reported that the effectiveness of conventional education decreases over time because children often lose motivation and engagement when learning relies primarily on passive information delivery.[6]

Consequently, recent oral health promotion programs have increasingly emphasized interactive, participatory, and technology-assisted educational approaches to facilitate sustained behavioral changes. Traditional oral health education approaches, such as lectures, posters, printed leaflets, and teacher-led demonstrations, have been extensively evaluated in school-based oral health promotion programs.[7–9]

These limitations have encouraged the development of technology-enhanced oral health education that actively engages children through interactive and immersive learning. Recent advances in digital health, particularly mobile applications, gamification, virtual reality (VR), and augmented reality (AR), have shown promising results in improving children's motivation, self-efficacy, and oral hygiene behaviors. Nevertheless, evidence regarding the effectiveness of AR-based applications in improving objectively assessed toothbrushing skills remains limited, especially in Indonesian elementary school settings.[9]

Therefore, educational interventions for children and adolescents should incorporate interactive, participatory, and visually engaging elements that correspond to their learning needs and preferences.[8,10,11] While these approaches provide basic awareness, their effectiveness in sustaining motivation and ensuring behavioral change has been shown to be limited.[12,13] Recent technological advances, particularly in digital health interventions, have created new opportunities to deliver more interactive, immersive, and personalized learning experiences.[7]

Recent systematic reviews have demonstrated that digital oral health education interventions, including mobile applications, serious games, and immersive technologies such as augmented reality (AR) and virtual reality (VR), are effective in improving oral health knowledge, self-efficacy, motivation, and oral hygiene behaviors among children. These technologies provide interactive, personalized, and engaging learning experiences that may enhance behavioral change beyond conventional educational approaches.[14]

Augmented reality (AR) technology has emerged as an innovative educational tool that enhances interactivity and user engagement, thereby offering a potential solution to the challenges encountered in health education. Augmented reality is an innovation that overlays digital content onto real-world

environments, thereby creating engaging and game-like educational scenarios.[15,] Several studies have demonstrated that AR-based health education can improve knowledge retention, enhance motor learning, and positively influence oral hygiene practices among children.[16,17]

Although previous studies have shown that digital and AR-based educational interventions can improve children's oral health knowledge and engagement, most have primarily evaluated knowledge acquisition rather than practical toothbrushing performance.[14,18] Furthermore, evidence regarding the effectiveness of AR-based oral health education among Indonesian elementary school children remains limited, particularly in real-world school settings. Therefore, further research is needed to determine whether AR-based learning can improve actual toothbrushing skills in this population.

HI Bogi (Halo Indonesia Bersama Dokter Gigi) is a mobile health application developed to support oral health education and prevention programs in Indonesia. By integrating AR technology, HI Bogi transforms toothbrushing education into a dynamic and interactive process, allowing children to visualize the correct brushing movements and receive immediate feedback.

Although previous studies have reported improvements in oral health knowledge and self-reported oral hygiene behaviors following the use of the HI Bogi app, evidence regarding its effectiveness in improving objectively assessed toothbrushing skills remains scarce. Unlike previous studies, the present study evaluates children's psychomotor toothbrushing performance using a standardized observational assessment following a 21-day AR-based intervention.[15,16]

The novelty of this study lies in its focus on the use of AR technology to improve practical toothbrushing skills rather than merely oral health knowledge, thereby providing new evidence on the role of immersive digital education in promoting effective oral hygiene practices among school-aged children. Therefore, this study aimed to analyze the effectiveness of the augmented reality-based HI Bogi application in improving toothbrushing skills among elementary school children using a quasi-experimental design

METHODS

This study used a quasi-experimental approach with a pretest and posttest design. This design was selected to evaluate changes in toothbrushing skills before and after the intervention, allowing for within-subject comparison. The target population was primary school children aged 9–12 years in Cimahi, West Java. This age group was chosen because children in this developmental stage can understand health-related instructions, establish long-term habits, and actively engage with digital learning tools.[4]

The inclusion criteria were as follows: (1) children aged 9–12 years, (2) currently enrolled in primary schools in Cimahi, and (3) willing to participate in all phases of the study, including pre-test, intervention, and post-test. The exclusion criteria included children with developmental or cognitive disorders that hindered independent app usage, systemic illnesses interfering with learning activities, and failure to complete the full intervention. The sample size was calculated using the formula for comparing two proportions based on the expected proportion of children demonstrating correct toothbrushing skills before and after the intervention.

The minimum sample size was determined using the formula, where Z_α is the standard normal deviate for the significance level, Z_β is the standard normal deviate for the desired statistical power, π is the pooled proportion, and P_1 and P_2 are the expected proportions. Based on a significance level of 5% ($Z_\alpha = 1.96$) and statistical power of 80% ($Z_\beta = 0.84$), the required minimum sample size was obtained. Assuming a significance level of 5% ($Z\alpha = 1.96$), statistical power of 80% ($Z\beta = 0.84$), pooled proportion (π) of 0.24, and expected proportions of

0.208 and 0.05, the calculated sample size was 75.37 subjects. Therefore, the required minimum sample size was rounded to 75.

The minimum required sample size was 75 participants. To increase statistical precision, compensate for potential attrition, and allow comparison between the intervention and control groups, 170 children were recruited. Participants were allocated to an intervention group (n = 85) and a control group (n = 85). The calculation yielded 75 participants per group, resulting in a total of 170. Sampling was conducted using simple random sampling from selected primary schools to ensure an equal probability of selection and to reduce sampling bias.

A two-stage cluster random sampling technique was used. In the first stage, public elementary schools in Cimahi City were considered sampling clusters, and several schools were randomly selected using a computer-generated random number sequence. In the second stage, eligible children aged 9–12 years from the selected schools were recruited according to the predefined inclusion and exclusion criteria until the required sample size was achieved.

Eligible participants were recruited from selected elementary schools using cluster random sampling methods. Schools were then assigned to either the intervention or control group to minimize contamination among participants. The intervention group consisted of 85 children, while the control group comprised 85 children.

The children in the intervention group received oral health education using the HI Bogi augmented reality application for 21 consecutive days. The application provided interactive toothbrushing instructions, real-time visualization of brushing movements, and guided practice sessions. Meanwhile, the children in the control group received conventional oral health education consisting of lectures, posters, and toothbrushing demonstrations delivered according to the school's routine oral health program. Toothbrushing skills were assessed at baseline and after the intervention using a standardized 13-item observational checklist administered by calibrated examiners.

The application contains multiple features, including teledentistry, telesurveys, brushing alarms, interactive quizzes, and AR-based modules, as shown in Figure 1.[15,16] The AR component allows children to visualize and simulate proper toothbrushing techniques (Fones method) using 3D animations, interactive markers, and gamified feedback.

The observational questionnaire was validated before data collection. Reliability analysis showed good internal consistency, with a Cronbach's alpha coefficient of 0.89, confirming the suitability of the instrument for assessing children's toothbrushing skills. The intervention lasted for 21 consecutive days.[12] The 21-day intervention period was selected based on behavioral learning principles, which emphasize that repeated practice over several weeks facilitates the acquisition of psychomotor skills and the establishment of health-related habits.

Daily repetition combined with immediate visual feedback provided by the HI Bogi AR application is expected to reinforce correct toothbrushing movements and promote behavioral consistency. Furthermore, previous school-based oral health education studies have demonstrated significant improvements in toothbrushing techniques and oral hygiene outcomes following interventions lasting approximately three weeks. Therefore, a 21-day intervention was considered sufficient to evaluate the short-term effectiveness of the HI Bogi AR application while ensuring participant adherence and minimizing loss to follow-up.[5]

During this period, the children were instructed to use the application daily, watch educational videos, participate in quizzes, and brush their teeth guided by the AR simulation. Teachers and parents assisted in ensuring compliance with the study protocols. Teachers and parents were instructed to support the participants' adherence to the study protocol throughout the 21-day intervention period. Teachers supervised the scheduled use of the HI Bogi application during school hours, reminded children to complete the assigned toothbrushing sessions, and

recorded their attendance and application use. Parents monitored the children's use of the application at home, encouraged them to complete the daily toothbrushing practice as instructed, and reminded them to adhere to the intervention schedule. Neither the teachers nor the parents provided additional toothbrushing instructions beyond the standardized protocol to avoid influencing the study outcome. The gamification elements, such as points and digital rewards, were included to enhance motivation and engagement, as illustrated in Figure 2.[14]

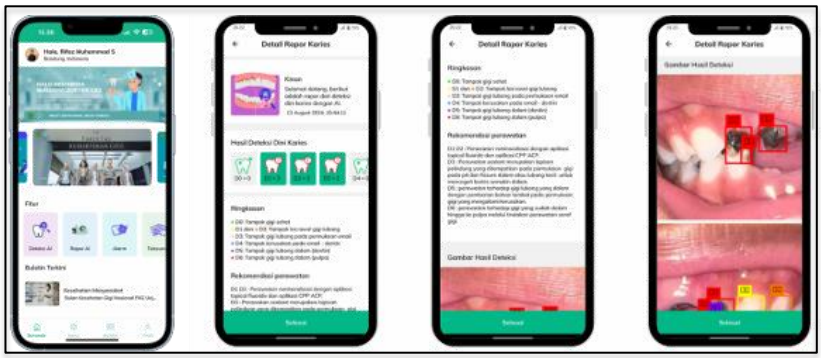

Figure 1. HI bogi application

Figure 2. Augmented reality intervention

Toothbrushing skills were assessed using a validated 13-item observational checklist. The measured items included brushing movements, tooth surface coverage, duration, and toothbrush replacement. Each item was scored dichotomously (1 = correct and 0 = incorrect). Scores ≥9 were categorized as good, and scores <9 were categorized as poor. Pre-test assessments were conducted prior to the intervention, and post-test assessments were performed immediately after 21 days of AR-based education. Data were analyzed using IBM SPSS Statistics software (version 25).

Descriptive statistics (mean, standard deviation, frequency, and percentage) were used to summarize the participants' characteristics and toothbrushing skill scores. Data normality was assessed using the Kolmogorov–Smirnov test. Within-group differences between pre- and post-intervention toothbrushing skill scores were analyzed using the paired t-test for normally distributed data or the Wilcoxon signed-rank test for non-normally distributed data. Between-group differences (intervention versus control) were analyzed using the independent *t*-test for normally distributed data and the Mann–Whitney U test for non-normally distributed data. Statistical significance was set at $P < 0.05$. Informed consent was obtained from the parents, teachers, and participants. All personal data were anonymized to ensure confidentiality and privacy of the participants.

RESULTS

This study obtained observational data on toothbrushing from 170 respondents, consisting of 85 respondents from the group using the AR intervention with the HI BOGI software application and 85 respondents from the control group of children aged 9-12 years at SDN Kota Cimahi in September-October 2025.

Table 1. Respondent characteristics among school children at SDN Kota Cimahi in 2025

Respondent Characteristics	Number	Percentage
Gender		
Male	92	54.12
Female	78	45.88
Age		
10 years old	35	20.59
11 years old	78	45.88
12 years old	57	33.53
School area		
Citereup Elementary School 2	85	50
Baros Elementary School 5	85	50

The results showed that the majority of respondents were male (54.12%) and aged 11 years (45.88%) in the Cimahi City area. (Table 1).

Tabel 2. Distribution of toothbrushing technique categories by study group before and after the intervention

Toothbrushing techniques	Intervention Group (AR) Pre-test n (%)	Intervention Group (AR) Post-test n (%)	Control Group (Conventional) Pre-test n (%)	Control Group (Conventional) Post-test n (%)
Good	12 (14.12)	83(97.65)	16(18.82)	77(90.59)
Poor	73(85.88)	2(2.35)	69(81.18)	8(9.41)

The toothbrushing techniques before the AR intervention among the respondents, who were children aged 9–12 years at SDN in Cimahi City in 2025, were assessed. Only approximately 12 respondents (14.12%) demonstrated good toothbrushing techniques, and 16 respondents (18.82%) were in the control group. The results of this study showed that 73 children in the intervention group had poor toothbrushing techniques (85.88%) and 69 children in the control group (81.18%) had poor toothbrushing techniques (Table 2). Analysis of toothbrushing techniques among children aged 9-12 years at SDN Kota Cimahi showed that 83 respondents (97.65%) in the AR group and 77 respondents (90.59%) in the control group performed good toothbrushing techniques after the intervention.

Table 3. Frequency distribution of toothbrushing techniques for elementary school children aged 9-12 years in Cimahi City in 2025

Variable	Mean ± SD
Pre-test intervention group	4.40 ± 3.771
Post-test intervention group	12.62 ± 0.707
pre-test control group	6.14 ± 3.475
post-test control group	11.45 ± 1.736

The mean score in the intervention group showed a marked increase from 4.40 ± 3.771 at pre-test to 12.62 ± 0.707 at post-test. In the control group, the mean score also increased from 6.14 ± 3.475 in the pre-test to 11.45 ± 1.736 in the post-test. However, the improvement in the intervention group was greater than that in the control group, indicating that the augmented reality innovation using the HI Bogi application was more effective in enhancing the measured outcomes than no intervention.

Table 4. Effect of Intervention on toothbrushing skills among children at SDN Kota Cimahi in 2025

	Toothbrushing results
Z	-15.192
Asymp. Sig. (2-tailed)	0.001

The Wilcoxon signed-rank test revealed a significant difference between the pre- and post-intervention results for toothbrushing skills. The test yielded a Z value of -15.192 with an Asymp. Sig. (2-tailed) of 0.001 ($p < 0.05$), indicating that the intervention led to a statistically significant improvement in toothbrushing outcomes. This suggests that the intervention effectively enhanced children's toothbrushing skills.

Both the intervention and control groups showed statistically significant improvements in toothbrushing skills following the intervention. The intervention group demonstrated a greater descriptive increase in the mean toothbrushing skill scores than the control group. However, because no statistical comparison between the groups was performed, it cannot be concluded that the HI Bogi AR application was significantly more effective than conventional oral health education.

DISCUSSION

The findings of this study demonstrated that children who received the HI Bogi AR intervention showed significant improvements in toothbrushing skills from pre-test to post-test. Based on the Wilcoxon signed-rank test, there was a statistically significant difference between the pre- and post-intervention scores ($Z = -15.192$; $p < 0.001$), indicating that the educational intervention using AR had a positive effect on improving children's brushing techniques. This aligns with the Health Belief Model (HBM) and Social Cognitive Theory (SCT) frameworks applied in this study, which emphasize that behavioral change occurs when individuals perceive personal susceptibility to disease and receive self-efficacy reinforcement through interactive learning experiences.[19,20]

The improvement observed in the intervention group supports previous literature suggesting that AR-based learning enhances engagement and retention by integrating virtual elements with real environments in real time, allowing children to visualize and practice correct brushing techniques directly.[21]

The use of AR in health education has been proven to increase attention, motivation, and comprehension levels among children compared with conventional methods. In the context of oral health education, AR can simulate realistic brushing movements, demonstrate areas commonly missed during brushing, and provide immediate feedback, enhancing motor learning and procedural memory. Similar findings were reported in a previous study, in which AR-based educational games significantly improved children's understanding and performance of toothbrushing techniques.[21–23]

In contrast, traditional oral health education typically delivered through posters, lectures, or two-dimensional videos often fails to maintain children's attention and motivation.[23–27] The findings of this study reaffirm that digital and interactive learning media, such as AR, are more effective in promoting behavioral change in school-age children. This improvement was not only cognitive but also behavioral, as indicated by the significant increase in the correct brushing frequency and technique accuracy after the intervention.

Our findings are consistent with those of Luai et al., who reported in a systematic review that immersive technologies, including augmented reality (AR) and virtual reality (VR), improve children's engagement, motivation, and oral health behaviors more effectively than conventional educational approaches. The review also highlighted that interactive learning environments promote active participation and facilitate the acquisition of psychomotor skills through real-time visual feedback.[14] Likewise, Murariu et al. found that technology-assisted oral

health education produced greater improvements in oral health knowledge and toothbrushing practices than traditional educational methods, although the magnitude of the effect varied across studies because of differences in intervention duration and outcome assessment.[24] These findings support the present study, in which AR-based education significantly improved both the frequency and accuracy of toothbrushing techniques among elementary school children.

Moreover, the HI Bogi application incorporates features such as brushing reminders, quizzes, and visual animations that reinforce healthy oral habits through gamification principles.[25] [26]These features are consistent with previous research highlighting the role of interactive digital media in shaping health-related behaviors among children.[27] The HI Bogi AR application provides interactive visual guidance, step-by-step toothbrushing instructions, and motivational reinforcement through gamification features, including points and digital rewards, to encourage correct toothbrushing practices.

The results of this study also align with those of Pullishery et al., who demonstrated that structured brushing programs improve plaque control and oral hygiene among children through repetitive supervised practice.[28] The AR component in this study effectively served as a digital supervisor, guiding children to brush their teeth correctly and consistently.

Taken together, these findings emphasize that the integration of AR technology into oral health promotion programs is not merely a novelty but represents a significant advancement in preventive dental education.[29] By delivering educational content in an engaging and interactive format, AR-based applications such as HI Bogi can strengthen children's knowledge, motivation, and behavioral compliance regarding proper oral hygiene practices. [30]

The limitation of this study is that the relatively short duration of the study did not allow for the evaluation of the long-term sustainability of behavioral changes and toothbrushing skill. Therefore, future studies with larger sample sizes, control groups, and longer follow-up periods are required to confirm and expand these findings.

CONCLUSION

Children who received the AR-based HI Bogi application showed significant improvements in toothbrushing skills following the intervention. The findings suggest that the application may serve as a promising interactive educational tool to support oral health promotion by enhancing children's engagement and reinforcing correct toothbrushing techniques.

The implication of this study is that integrating augmented reality (AR)-based educational media into school oral health promotion programs may improve children's acquisition of proper tooth brushing skills through a more engaging and interactive learning experience. Furthermore, the HI Bogi application has the potential to complement conventional oral health education by providing consistent technology-assisted instruction that can be implemented in schools and community-based oral health programs. However, because no statistical comparison of the magnitude of improvement between the intervention and control groups was performed, the present findings should not be interpreted as evidence that the HI Bogi application is superior to conventional oral health education methods. Further studies using appropriate between-group analyses, randomized controlled designs, and longer follow-up periods are needed to confirm its comparative effectiveness and long-term impact on children's oral health behaviors.

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REFERENCES

1. Ministry of Health of the Republic of Indonesia. Indonesia Health Survey (SKI) 2023. Jakarta: Ministry of Health of the Republic of Indonesia; 2023.
2. Shokravi M, Khani-Varzgan F, Asghari-Jafarabadi M, Erfanparast L, Shokrvash B. The impact of child dental caries and the associated factors on child and family quality of life. Int J Dent. 2023:4335796. https://doi.org/10.1155/2023/4335796
3. Nazari A, Hajihashemi M, Safavi SR, Ataei R, Hosseinnia M. Health promotion theory-based educational interventions for improving oral health in children and adolescents: a systematic review and meta-analysis. BMC Oral Health. 2025;25:1153. https://doi.org/10.1186/s12903-025-06549-3
4. Bakhtiarvand SZ, Rahaei Z, Sadeghian HA, Fatehi F, Soltani S, Zareiyan A, et al . The constructs of health literacy in children: a systematic review. BMC Public Health. 2025;25:3352. https://doi.org/10.1186/s12889-025-24573-4
5. Ly-Mapes O, Jang H, Al Jallad N, Rashwan N, Castillo DA, Lu X, et al. Effectiveness of interventions on improving early-life dental care utilization: a systematic review and meta-analysis. Quintessence Int. 2024;55(9):722-32. https://doi.org/10.3290/j.qi.b5640008
6. Stein C, Santos NML, Hilgert JB, Hugo FN. Effectiveness of oral health education on oral hygiene and dental caries in schoolchildren: systematic review and meta-analysis. Community Dent Oral Epidemiol. 2018;46(1):30-7. https://doi.org/10.1111/cdoe.12325
7. Scheerman JFM, Van Meijel B, Van Empelen P, Verrips HW, Van Loveren C, Van der Heijden GJMG, et al. The effect of using a mobile application ("WhiteTeeth") on improving oral hygiene: a randomized controlled trial. Int J Dent Hyg. 2020;18:73-83. https://doi.org/10.1111/idh.12415
8. Xiang B, Wong HM, Perfecto AP, McGrath CPJ. The effectiveness of behavioral interventions to improve oral health in adolescents at different periods of follow-up: a systematic review and meta-analysis. Patient Educ Couns. 2020;103(4):725-33. https://doi.org/10.1016/j.pec.2019.11.030
9. Chen J, Ying Y, Pang M, Chen J, Kang T, Xuan P, et al. The application of gamification in children's oral health management: systematic review. J Med Internet Res. 2025;27:e75541. https://doi.org/10.2196/75541
10. Chauhan M, Chand S, Khan M, Shaktawat N, Ali S, Kavitake RD. Effectiveness of conventional versus game-based oral health education on oral hygiene performance of 12-15-year-old private school children in Jodhpur city: a randomized controlled clinical trial. Int J Prev Clin Dent Res. 2025;12(2):15-7. https://doi.org/10.4103/ijpcdr.ijpcdr_6_25
11. Romalee W, Tsai FT, Hsu YC, Hsu ML, Wang DH. A mobile augmented reality-integrated oral health education for community dwelling older adults: a pilot study. J Dent Sci. 2023;18(4):1838-44. https://doi.org/10.1016/j.jds.2023.07.019
12. El Kirat H, van Belle S, Khattabi A, Belrhiti Z. Behavioral change interventions, theories, and techniques to reduce physical inactivity and sedentary behavior in the general population: a scoping review. BMC Public Health. 2024;24(1). https://doi.org/10.1186/s12889-024-19600-9
13. Jeon B, Oh J, Son S. Effects of tooth brushing training, based on augmented reality using a smart toothbrush, on oral hygiene care among people with intellectual disability in Korea. Healthcare (Basel). 2021;9(3):348. https://doi.org/10.3390/healthcare9030348
14. Luai AF, Malek AA, Hassan EH, Sabri BAM, Radzi NAM. Effectiveness of immersive technologies in oral health promotion and education: a systematic review. J Dent. 2024;150:105324. https://doi.org/10.1016/j.jdent.2024.105324
15. Gurav KM, Shetty V, Vinay V, Bhor K, Jain C, Divekar P. Effectiveness of oral health educational methods among school children aged 5-16 years in improving their oral health status: a meta-analysis. Int J Clin Pediatr Dent. 2022;15(3):338-49. https://doi.org/10.5005/jp-journals-10005-2395
16. Deshmukh S, Mahesh A, Dey S. Impact of augmented reality guided toothbrushing on oral hygiene parameters among 6-8 years-old children: a pilot trial. Pesqui Bras Odontopediatria Clin Integr. 2024;24:e2024089. https://doi.org/10.1590/pboci.2024.089
17. Ribeiro Amantini SNS, Pascotto Montilha AA, Antonelli BC, Leite KTM, Rios D, Cruvinel T, et al. Using augmented reality to motivate oral hygiene practice in children: protocol for the development of a serious game. JMIR Res Protoc. 2020;9(1). https://doi.org/10.2196/10987
18. Saini D, Jain R, Thakur A. Dental caries early detection using convolutional neural network for teledentistry. In: 2021 7th International Conference on Advanced Computing and Communication Systems (ICACCS). IEEE; 2021. p.958-63. https://doi.org/10.1109/ICACCS51430.2021.9442001

19. Alamer AS. Behavior change theories and models within health belief model research: a five-decade holistic bibliometric analysis. Cureus. 2024;16(6):e63143. https://doi.org/10.7759/cureus.63143
20. Islam KF, Awal A, Mazumder H, Munni UR, Majumder K, Afroz K, et al. Social cognitive theory-based health promotion in primary care practice: a scoping review. Heliyon. 2023;9:e14889. https://doi.org/10.1016/j.heliyon.2023.e14889
21. Fuentes C, Gómez S, De Stasio S, Berenguer C. Augmented reality and learning-cognitive outcomes in autism spectrum disorder: a systematic review. Children (Basel). 2025;12(4):493. https://doi.org/10.3390/children12040493
22. Sharma S, Saxena S, Naik SN, Bhandari R, Shukla AK, Gupta P. Comparison between conventional, game-based, and self-made storybook-based oral health education on children's oral hygiene status: a prospective cohort study. Int J Clin Pediatr Dent. 2021;14(2):273-7. https://doi.org/10.5005/jp-journals-10005-1811
23. Brandon KO, Vinci C, Kleinjan M, Hernandez LM, Sawyer LE, Sutton SK, et al. Testing augmented reality for eliciting cue-provoked urges to smoke: toward moving cue-exposure into the real world. Nicotine Tob Res. 2021;23(5):861-5. https://doi.org/10.1093/ntr/ntaa259
24. Murariu A, Bobu L, Geleţu GL, Stoleriu S, Iovan G, Vasluianu RI, et al. The impact of mobile applications on improving oral hygiene knowledge and skills of adolescents: a scoping review. J Clin Med. 2025;14(9):2907. https://doi.org/10.3390/jcm14092907
25. Naghavi M, Ong KL, Aali A, Ababneh HS, Abate YH, Abbafati C, et al. Global burden of 288 causes of death and life expectancy decomposition in 204 countries and territories and 811 subnational locations, 1990-2021: a systematic analysis for the Global Burden of Disease Study 2021. Lancet. 2024;403(10440):2100-32. https://doi.org/10.1016/S0140-6736(24)00367-2
26. Moreira R, Silveira A, Sequeira T, Durão N, Lourenço J, Cascais I, et al. Gamification and oral health in children and adolescents: scoping review. Interact J Med Res. 2024;13:e35132. https://doi.org/10.2196/35132
27. Shaluhiyah Z, Qatrannada SA, Kusumawati A, Miah MS. The effect of digital health intervention in promoting healthy behavior: a systematic scoping review on strategies to prevent non-communicable diseases. Dialogues Health. 2025;7:100258. https://doi.org/10.1016/j.dialog.2025.100258
28. Pullishery F, Abuzenada BM, Alrushnudi NM, Alsafri MM, Alkhaibari WM, Alharbi MF, et al. Comparison of efficacy of different supervision methods of toothbrushing on dental plaque scores in 7-9-year-old children. Int J Clin Pediatr Dent. 2021;14(2):263-8. https://doi.org/10.5005/jp-journals-10005-1927
29. Puleio F, Tosco V, Pirri R, Simeone M, Monterubbianesi R, Lo Giudice G, Lo Giudice R. Augmented reality in dentistry: enhancing precision in clinical procedures-a systematic review. Clin Pract. 2024;14(6):2267-83. https://doi.org/10.3390/clinpract14060178
30. Mehta V, Mathur A, Chaurasia H, Obulareddy VT, D'Amico C, Fiorillo L. A brief review on engaging and interactive learning for children: exploring the potential of metaverse-based oral health promotion. Int J Dent. 2024;2024:6679356. https://doi.org/10.1155/2024/6679356

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