Systematic Review

Augmented reality interventions in oral health promotion and education: a systematic review

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Received: 22 January 2026
Revised: 25 Februari 2026
Accepted: 20 March 2026
Published: 31 March 2026
DOI: 10.24198/pjd.vol38no1.67298

p-ISSN 1979-0201
e-ISSN 2549-6212

Citation:
Wahyuningsih, I. Hanindriyo, L. Widiati, S. Augmented reality interventions in oral health promotion and education: a systematic review. Padj J Dent, Padjajaran J. Dent. March. 2026; 38(1): 196-205.

ABSTRACT

Introduction: Augmented reality (AR) is an innovative technology being increasingly utilized in oral health promotion and education. This systematic review aimed to map and describe the types of augmented reality interventions, target populations, outcomes, and implementation challenges in oral health promotion and education. **Methods:** This systematic review was conducted in accordance with PRISMA-ScR guidelines. A systematic literature search was performed across Google Scholar, ScienceDirect, and PubMed, to identify articles published between 2020 and 2024. Studies were included based on predefined criteria focusing on augmented reality interventions for oral health promotion and education. Exclusion criteria comprised review articles, editorials, commentaries, and studies without full-text availability. Study selection was conducted independently by two reviewers. **Results:** A total of 456 articles were identified, of which nine studies met the inclusion criteria. Most studies targeted children (55.5%) and used non-randomized designs (77.8%). Augmented Reality interventions included smart toothbrushes, serious games, and mobile applications. Overall, these interventions improved oral health knowledge, motivation, oral hygiene status, and brushing skills. **Conclusion:** This systematic review underscores the potential of AR as an innovative tool in oral health education. AR interventions have shown effectiveness in improving knowledge, motivation, self-efficacy, and health behaviors across diverse populations, particularly among children and vulnerable groups. However, while the findings are promising, limitations related to study design, sample sizes, and intervention durations necessitate further research.

KEYWORDS

Augmented reality, oral health promotion, dental health education, systematic review

INTRODUCTION

Oral health is an integral aspect of an individual's overall well-being, influencing physical, psychological, and social quality of life.[1] The high prevalence of oral diseases among both adult and pediatric populations underscores the urgent need to raise public awareness regarding the importance of maintaining oral health. According to the World Health Organization (WHO), in 2024, approximately 3.5 billion people worldwide are expected to be affected by oral diseases, including 2 billion individuals with permanent tooth decay and 514 million children with primary tooth caries.[2] Oral health problems not only cause pain but also lead to difficulties in chewing, speaking, and smiling, which ultimately diminish an individual's quality of life through nutritional impairments and reduced self-confidence.[1,3]

Educational programs in schools and community outreach initiatives are essential for improving oral health, in accordance with WHO recommendations that advocate for preventive approaches through oral health education.[4] Oral

health knowledge is a key element in the prevention of dental caries. However, public awareness remains low due to limited access to information and education Many individuals have yet to adopt the habit of brushing their teeth twice daily, and this lack of habit is a major risk factor for the development of caries.[5] Therefore, there is a need for innovative, interactive, engaging, and easily accessible oral health education strategies to enhance understanding and promote positive behavioral change.[6,7]

Oral health education has been shown to significantly improve oral hygiene practices and reduce the risk of dental caries among schoolchildren, highlighting the critical role of educational interventions in preventive oral health strategies. [8] Oral health promotion utilizing digital technologies can reach a broader audience and provide a more immersive educational experience, thereby facilitating improved health behaviors and reducing disparities in access to health information.[9,10] Digital oral health initiatives are projected to promote oral health, prevent oral diseases, and extend outreach to a larger population. By leveraging digital technology, oral health education is expected to become more interactive and engaging, encouraging active community participation in maintaining their oral health.[11]

Augmented Reality (AR) technology offers an innovative solution capable of addressing various challenges in health education by enhancing interactivity and capturing users' attention.[12] Augmented Reality integrates virtual objects, both two-dimensional and three-dimensional, with the real environment to create an immersive educational experience.[13] A key advantage of AR lies in its accessibility through portable devices such as smartphones and tablets, enabling flexible learning. Augmented Reality can present information in a more engaging manner, for example, through animations and interactive visualizations, thereby improving user comprehension.[14]

Recent studies indicate that AR technology is effective in enhancing knowledge, skills, and motivation, particularly among children and vulnerable populations.[15–19] Conventional oral health education methods, such as lectures, direct counseling, and printed media (posters, leaflets, brochures), are commonly used in community health programs. Although these methods can improve basic oral health knowledge in the short term, they often show decreased knowledge retention and behavioral relapse over time due to limited interactivity and passive information delivery.[20]

Behavior change is facilitated through observational learning and the development of self-efficacy, which are strengthened through interactive and experience-based educational approaches rather than passive information delivery.[21] In contrast to conventional education, AR represents an interactive digital education approach that integrates visual and verbal information simultaneously. This immersive and interactive learning experience enables active user participation and provides real-time visual guidance, thereby enhancing engagement, understanding, motivation, and retention of oral health information compared to conventional education methods.[22]

Although AR has been widely utilized in dental education for healthcare professionals, its application in oral health promotion remains limited, with most research focusing more on Virtual Reality (VR).[10,12,23] Therefore, a knowledge gap exists regarding the effectiveness of AR in oral health promotion. To date, no systematic review has comprehensively mapped the types of AR interventions, target populations, outcomes, and implementation challenges in oral health promotion and education.

Therefore, this systematic review provides novel insights by systematically mapping the existing evidence on the use of AR in oral health promotion and education. This systematic review aimed to map and describe the types of augmented reality interventions, target populations, outcomes, and implementation challenges in oral health promotion and education.

METHODS

This systematic review aimed to systematically map existing evidence, identify research gaps, and provide recommendations regarding the implementation of augmented reality in oral health promotion and education. The review was reported in accordance with the PRISMA Extension for systematic review (PRISMA-ScR) guidelines.[24] This review did not involve a registered protocol, as the objective was to map existing evidence rather than to assess intervention effectiveness. Literature identification was performed through a systematic search of electronic databases, including Google Scholar, PubMed, and ScienceDirect.

The search strategy focused on combining keywords relevant to AR and oral health promotion. The electronic database search was conducted between April and June 2024, with the final search performed in June 2024, and was limited to articles published between January 2020 and December 2024. Keywords were grouped into two main categories: (1) Augmented Reality (AR) and (2) oral health promotion and education. Boolean operators "OR" and "AND" were employed to combine these keywords. An example of the keyword combination used is: ("Augmented Reality" OR "AR") AND ("oral health promotion" OR "oral health education" OR "dental health promotion" OR "dental health education"). The search strategy was first developed and applied in PubMed and subsequently adapted for the other databases. In addition to electronic searches, manual searches were conducted by reviewing the reference lists of relevant articles to ensure comprehensive literature coverage.

The search results from all databases were combined, yielding a total of 456 records (Google Scholar n = 228, PubMed n = 153, ScienceDirect n = 66, and manual searching n = 9). After removing duplicates (n = 91), 365 articles remained for title and abstract screening. A total of 268 articles were excluded based on the predefined inclusion and exclusion criteria. Subsequently, 97 articles were assessed for eligibility through full-text review, and nine studies were ultimately included in this review.

The inclusion criteria for studies were as follows:(1) Studies focusing on AR interventions as a medium for oral health promotion and education; (2) Studies involving populations of children, adults, elderly individuals, and/or persons with special needs; (3) Studies published in English; (4) Studies published within the last five years, specifically between 2020 and 2024. Exclusion criteria included: (1) Studies categorized as reviews (including systematic reviews and meta-analyses), editorials, letters to the editor, or commentaries; (2) Studies available only as abstracts without full-text availability.

The study selection was conducted independently by two researchers (LH and IW) who screened titles and abstracts based on the inclusion and exclusion criteria. Full-text evaluation was also performed independently by the same researchers. Any disagreements during the selection process were resolved through discussion. If consensus was not reached, a third researcher (SW) was consulted to provide input and assist in making the final decision. The entire selection process was documented using a PRISMA flow diagram.

Data extraction was carried out using a pre-tested form to ensure validity and reliability. The collected information included author names, publication year, country of study, population characteristics, type of AR used, intervention objectives, outcomes, and main findings. Extracted data were then analyzed using descriptive and narrative methods.

Descriptive analysis summarized study characteristics, including the number of publications per year, country of origin, study design, target population, and types of AR employed. Narrative analysis was used to synthesize findings across studies, identify types of AR applications, main outcomes, as well as advantages and limitations of using AR as a medium for oral health promotion. Formal risk of

bias assessment, quantitative data calculation, and meta-analysis were not performed, as these were beyond the scope of this systematic review. Formal risk of bias assessment was not conducted, as this study was designed as a systematic review aimed at mapping existing evidence rather than evaluating intervention effectiveness.

RESULTS

A systematic search of three electronic databases—Google Scholar, PubMed, and ScienceDirect—along with manual searches, yielded a total of 456 articles. The removal of duplicates eliminated 91 articles, leaving 365 articles for the screening process. Title and abstract screening resulted in the exclusion of 268 articles due to the following reasons: 17 were review articles; 51 did not focus on AR interventions as a medium for oral health promotion and education; 5 were not published in English; and 24 were published outside the specified date range (before 2020 or after 2024). After applying the inclusion and exclusion criteria, nine studies met the eligibility requirements for in-depth analysis. The PRISMA flow diagram illustrates the selection process (Figure 1).

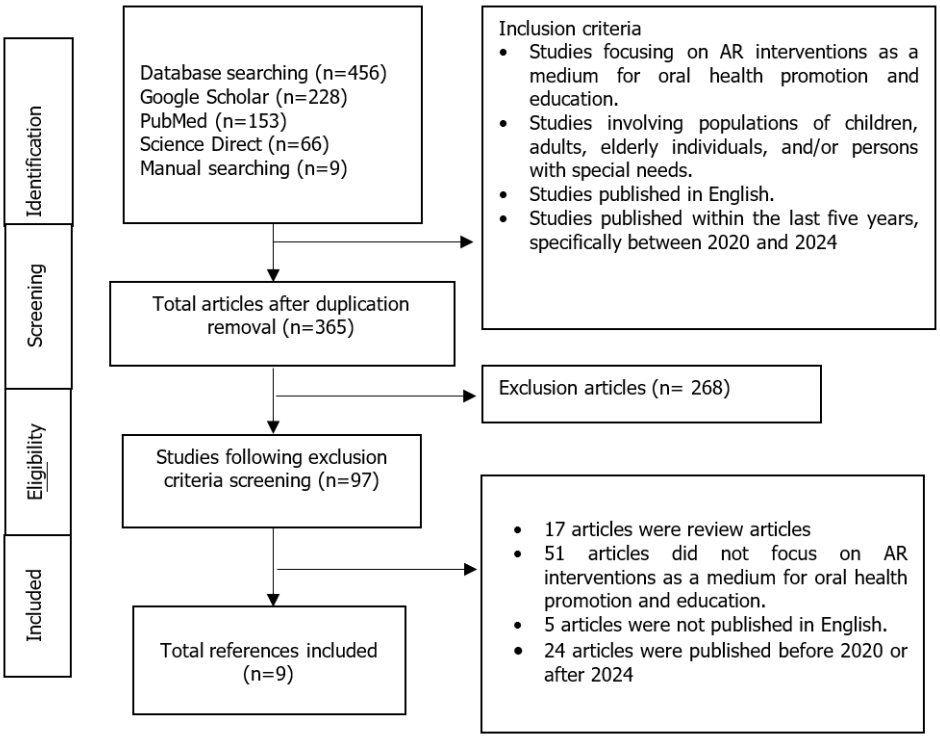

Figure 1. PRISMA Flowchart

A total of nine studies were included in this systematic review. Most of the included studies employed non-randomized intervention designs (77.8%), while randomized controlled trials accounted for 22.2%. The publications were relatively recent, with the majority published between 2023 and 2024. Studies were conducted predominantly in East Asia and the Pacific region, followed by Latin America and South Asia. In terms of country income classification, most studies were carried out in high-income and upper middle-income countries. The target populations varied, with children being the most frequently studied group, followed by adults or elderly populations, mothers and children, and individuals with intellectual disabilities. The detailed characteristics of the included studies are presented in Table 1.

Table 1. Characteristics of studies included in the systematic review on augmented reality for oral health promotion (n = 9)

Category	Number of Studies (n=9)	Percentage (%)
Study Design		
Randomized Controlled Trial (RCT)	2	22.2%
Non-Randomized Studies of Interventions (NRSI)	7	77.8%
Year of Publication		
2020	1	11.1%
2021	1	11.1%
2022	1	11.1%
2023	3	33.3%
2024	3	33.3%
Country/Setting by Income [25]		
High-income country	4	44.5%
Upper middle-income country	4	44.5%
Lower middle-income country	1	11.1%
Geographical Region		
East Asia and Pacific	7	77.8%
Latin America and the Caribbean	1	11.1%
South Asia	1	11.1%
Target Population		
Children	5	55.5%
Adults/Elderly	2	22.2%
Mothers and children	1	11.1%
Individuals with intellectual disabilities	1	11.1%
Type of AR Intervention		
AR smart toothbrush	4	44.4%
AS serious game	2	22.2%
Mobile AR application	2	22.2%
AR educational book/package	1	11.1%
Main Outcomes Assessed		
Oral health knowledge	6	66.7%
Oral hygiene status (plaque, gingiva)	4	44.4%
Motivation / engagement	5	55.6%
Self-efficacy	2	22.2%
Brushing skills/performance	3	33.3%

Note: One study may report more than one outcome; therefore, the cumulative percentage exceeds 100%.

Table 1 summarizes the main characteristics of the nine included studies. Two studies (22.2%) used randomized controlled trial (RCT) designs, while seven (77.8%) were non-randomized intervention studies (NRSI). Most studies (66.6%) were published in 2023 and 2024. In terms of geographical distribution, most studies were conducted in the East Asia and Pacific region (77.8%). Based on country income classification, 44.5% of studies were conducted in high-income countries and 44.5% in upper-middle-income countries, with one study from a lower-middle-income country. Children were the most frequently studied population (55.5%), followed by adults or elderly populations, mother–child groups, and individuals with intellectual disabilities. The most common AR interventions included AR-based smart toothbrushes and serious games, and the main outcomes assessed were oral health knowledge, oral hygiene status, motivation or engagement, self-efficacy, and brushing skills.

Tabel 2. Characteristics of Individual Studies

No.	Author / Year	Research Objective	Country	Study Design	Population / Sample	Type of AR Intervention	Main Findings	Strengths	Limitations
1	Amantini et al., 2020[26]	To develop an AR-based serious game protocol to motivate oral hygiene	Brazil	Development protocol (non-randomized)	Children aged 6–10 years	AR serious game with Kinect sensor	Protocol designed to enhance motivation, knowledge, and self-confidence	Innovative AR and motion sensor integration	No effectiveness evaluation reported
2	Jeon et all., 2021 [16]	To evaluate AR-based smart toothbrush training for individuals with intellectual disabilities	Korea	Quasi-experimental (pre–post)	30 adults with intellectual disabilities (15 experimental, 15 control)	AR smart toothbrush	Improved oral hygiene index and brushing performance ($p < 0.001$)	Interactive AR technology, 3D sensor	Small sample, limited generalizability, short duration, non-randomized
3	Hapsari., et al., 2022 [27]	To develop and evaluate an AR educational game using the IRVO model	Indonesia	Quasi-experimental (NRSI), product development	Elementary school children (sample size not specified)	AR serious game (IRVO model)	Increased motivation and understanding; high user interest (>75%)	Innovative IRVO-based AR design	Unspecified age and participants, limited evaluation, no long-term data
4	Maula., et al., 2023 [28]	To improve oral health behavior and hygiene in parents and preschool children	Indonesia	Quasi-experimental	40 parents & 40 preschool children	AR educational book	Significant increase in knowledge, attitude, behavior; plaque index reduction ($p<0.05$)	Innovative AR book combining illustrations & 3D	Limited sample, short duration and follow-up, limited technology access
5	Min-Ji Park et al., 2023 [29]	To assess plaque removal effectiveness of an AR smart toothbrush in children	Korea	RCT, double-blind crossover	20 children aged 5–12 years (10 AR, 10 control)	AR smart toothbrush	Significant reduction in plaque and gingival bleeding; increased motivation ($p < 0.01$)	Objective controlled design, increased motivation	Small sample, short duration, limited generalizability
6	Romalee et al., 2023 [30]	To develop and evaluate mobile AR oral health education for older adults	Taiwan	Pilot study, quasi-experimental pre-post	24 elderly aged 65–93 years	Mobile AR application	Improved knowledge and self-efficacy ($p < 0.01$)	Mobile AR accessible to elderly	Small sample, no control group, short follow-up
7	Deshmukh et al., 2024 [31]	To evaluate AR-guided toothbrushing in children	India	Non-randomized, parallel, single-blind	32 children aged 6–8 years (2 groups)	AR smart toothbrush	Reduced plaque and gingival bleeding; high acceptance ($p < 0.001$)	Effective interactive AR technology, objective control	Small sample, short duration, non-randomized
8	Rahmasari S et al., 2024 [32]	To assess the impact of an integrated AR oral health education package	Indonesia	Pre-post without control	49 children aged 7 years	AR education package	Significant increase in oral health knowledge ($p < 0.05$)	Interactive AR media, simple approach	No control group, follow-up duration not specified
9	Romalee et al., 2024 [17]	To compare mobile AR education with lectures and no intervention	Taiwan	Randomized controlled trial	75 community elderly (61 analyzed)	Mobile AR application	Mobile AR improved knowledge, self-efficacy, oral health status; usability needs enhancement	RCT, comprehensive evaluation	2-week follow-up, limited to Taipei area

Table 2 summarizes nine studies that evaluated various augmented reality (AR) interventions for oral health promotion and education across diverse population groups. The types of interventions identified include AR-based serious

games, smart toothbrushes with AR features, interactive AR educational books, AR mobile applications, and integrated oral health education packages incorporating AR. Most studies targeted children of preschool and elementary school age; however, some also involved elderly individuals, parents, and persons with intellectual disabilities.

Study designs varied, including randomized controlled trials (RCTs), quasi-experimental studies, pilot studies, and protocol development studies. Two studies used RCT designs, while most employed quasi-experimental or pre-post designs without control groups. Sample sizes were generally small, ranging from 20 to 75 participants. This variety in interventions and study designs reflects ongoing innovation in AR tailored to diverse populations and underscores the exploratory nature of current research in this field.

Almost all studies reported that AR-based interventions effectively enhanced oral health knowledge, motivation, self-efficacy, and toothbrushing behavior. They also reduced plaque index and gingival bleeding. The use of AR serious games and smart toothbrushes among children proved effective in increasing motivation and brushing effectiveness, while mobile AR applications and AR educational books for elderly individuals, mothers, and children improved knowledge and self-efficacy. Studies involving individuals with intellectual disabilities also demonstrated significant improvements in oral hygiene following AR smart toothbrush training.

However, most studies faced limitations such as small sample sizes, short intervention durations, and the absence of control groups in some cases. Challenges related to usability and accessibility of AR technology, particularly among the elderly population, were frequently noted. Overall, these findings affirm the potential of AR as an innovative and effective medium for oral health education, though further research with stronger study designs and broader population coverage is needed to confirm these results

DISCUSSION

This systematic review indicates that the effectiveness of AR interventions depends on the target population and type of intervention. Compared to conventional educational methods, AR-based approaches offer advantages in improving knowledge, motivation, and oral health behaviors. These findings are consistent with previous studies in digital health education, which have demonstrated that AR and other interactive technologies enhance user engagement and facilitate behavior change more effectively than traditional methods. A study by Romalee et al.[17] demonstrated that mobile AR–based oral health education significantly improved knowledge and self-efficacy among older adults and showed better retention compared to tradisional methods. …..

Children constitute a primary target group for AR oral health education. A study by Amantini et al. and Hapsari et al. developed AR-based serious games incorporating gamification elements, which provided interactive and enjoyable learning experiences that encouraged proper toothbrushing behaviors.[26,27] These findings are consistent with previous research highlighting the effectiveness of gamification in improving engagement and learning outcomes among children.[23]

Smart toothbrushes equipped with AR features have also proven effective in reducing plaque and gingival bleeding while enhancing children's motivation and satisfaction during brushing. Jeon et al. reported significant improvements in oral hygiene among children and adults with intellectual disabilities following AR smart toothbrush training.[16] Similarly, studies by Min-Ji Park et al. and Deshmukh et al. documented significant reductions in plaque and gingival bleeding scores in children using AR smart toothbrushes.[29,31]These results suggest that AR-integrated smart toothbrushes provide real-time visual feedback that supports correct brushing techniques.

Among adults and elderly populations, mobile AR applications have yielded positive outcomes in oral health education. Romalee et al. (2023, 2024) demonstrated that mobile AR significantly improved elderly individuals' knowledge and self-efficacy compared to conventional education or no intervention, despite usability challenges.[17,30] This underscores the importance of user-friendly app design tailored to older adults, such as large fonts, simple navigation, and audio instructions to enhance accessibility. Such user-centered design principles are critical to adapting AR for diverse age groups and needs.[33–35]

These innovations reflect AR's adaptability across various educational media and its strong potential to enhance oral health promotion effectiveness in multiple populations. Moreover, the findings resonate with broader health education literature, which shows that AR can improve patient understanding of complex medical information, reduce anxiety, and increase engagement.[36–38] For instance, 3D animations used in preoperative consultations have been shown to enhance patient recall of information.[39,40] This evidence suggests that AR's immersive and personalized approach extends beyond oral health, supporting sustained behavioral change in general health education.

Recent systematic reviews confirm that immersive technologies, including AR, effectively improve knowledge, attitudes, and self-efficacy related to oral health among children, adolescents, and adults. AR educational games, in particular, boost motivation and engagement in oral hygiene practices.[12] Findings from various studies indicate that AR is an effective and innovative medium for oral health education across multiple settings, including schools, communities, and healthcare facilities.

Therefore, the use of AR in oral health education not only supports knowledge enhancement but also aligns with broader trends in digital health education that emphasize interactive and user-centered approaches. These findings are relevant for healthcare providers, educators, policymakers, and technology developers, as they can inform strategies for implementing AR interventions effectively.

However, AR intervention effectiveness is not universal. Elderly populations require simpler interfaces and additional support to optimize technology use. Positive attitudes, personal characteristics, and cognitive abilities also influence technology adoption among older adults, emphasizing the need for usability and accessibility considerations in AR design.[34,35] Theories such as multimedia learning theory explain the effectiveness of AR interventions by highlighting the advantages of simultaneous visual and auditory information processing in improving knowledge retention. In addition, contemporary behavioral frameworks help explain how attitudes, perceived norms, self-efficacy, and observational learning mechanisms facilitate the adoption and maintenance of positive oral health behaviors.[21,22,41]

Augmented Reality (AR) represents an innovative and effective medium for oral health education across schools, communities, and healthcare settings. AR interventions, including gamified approaches for children, AR smart toothbrushes for children and individuals with special needs, and user-centered mobile AR applications for adults and the elderly, can enhance knowledge, motivation, and oral hygiene behaviors. Effective implementation requires collaboration among technology developers, healthcare professionals, and educators, as well as attention to inclusivity, cultural adaptation, usability, and accessibility to ensure adoption across diverse populations.

The limitation of this systematic review is the small number of studies, their concentration in East Asia and the Pacific, and limited diversity of target populations. Additionally, many studies employed quasi-experimental or pre-post designs, had short durations, and lacked long-term follow-up, which limits certainty and generalizability. Future research should involve larger, more diverse populations, employ rigorous randomized controlled trials, extend follow-up periods, and prioritize usability and accessibility, especially for elderly individuals

and people with special needs. Addressing these gaps will strengthen the evidence base and inform effective implementation of AR interventions in oral health education.

CONCLUSION

This systematic review maps the existing evidence on augmented reality (AR) interventions in oral health promotion, highlighting their positive impact on knowledge, motivation, self-efficacy, toothbrushing performance, and hygiene status across diverse populations. AR methods, including gamified applications and smart toothbrushes, offer an effective and engaging approach to support health behavior changes, especially among children and vulnerable groups.

The implication of this systematic review is that AR can be effectively integrated into educational programs, community initiatives, and healthcare services**,** aligning with behavioral and multimedia learning theories. However, evidence is limited by small sample sizes and methodological constraints. Future research should focus on larger, more diverse populations and longer follow-up evaluations to enhance the effectiveness and sustainability of AR in oral health education.

Acknowledgement: No declare
Author Contributions: Conceptualization, IW and LH; methodology, IW and LH; formal analysis, IW; investigation, IW and LH; data curation, IW and LH; writing original draft preparation, IW; writing review and editing, IW, LH and SR; supervision, SR; project administration, SR. All authors have read and agreed to the published version of the manuscript.
Funding: This research received no external funding
Institutional Review Board Statement: Not requiring ethical approval.
Informed Consent Statement: Not applicable.
Data Availability Statement: Not applicable.
Conflicts of Interest: The authors declare no conflict of interest.

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