

Gamification and Oral Health in children and adolescents - scoping review

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Abstract

Background: Oral health is a vital determinant of overall well-being and quality of life. Treating oral pathologies can be expensive and is often not covered by universal healthcare. Individual behaviors, such as oral hygiene practices, plaque control, and dietary habits, play a central role in oral health. Motivation is a crucial factor in promoting behavior change, and gamification offers a means to boost health-related knowledge and encourage positive health behaviors.

Objective: Evaluate the impact of gamification and its mechanisms on oral healthcare of children and adolescents.

Methods: A systematic search covered multiple databases: Pubmed/Medline, PsycINFO, The Cochrane Library, Science Direct, and Lilacs. Grey literature, conference proceedings, and WHOQOL internet resources were considered. Studies from January 2013 to December 2022 were included, except for Pubmed/Medline, which was searched until January 2023.

Fifteen studies were selected following PRISMA guidelines. Eligibility criteria were: peer-reviewed, full-text, empirical research related to gamification in oral healthcare, reports of impact and oral healthcare outcomes. Exclusion criteria encompassed duplicate articles, unavailable full texts, non-original articles, non-digital game-related, non-oral health-related, and protocol studies. Selected studies were scrutinized for gamification mechanisms and outcomes. Two main questions were raised "Does gamification in oral healthcare impact oral health?" and "Does oral healthcare gamification enhance health promotion and literacy?" PICO framework guided the scoping review.

Results: Initially, 617 records were obtained from five databases and grey literature sources. After removing duplicates and records that did not meet inclusion criteria, 15 records were selected. Sample size in the selected studies ranged from 34 to 190 children and adolescents.

A significant portion, 73% (11/15), of the studies discussed oral self-care applications supported by evidence-based oral health. The most clearly defined information's in the applications were "brushing time" 100% (11/11) and "daily amount brushing" 91% (10/11). Most studies, 73% (11/15), mentioned oral healthcare behavior change techniques and included "prompt intention formation" 42% (11/26), "providing instructions" 42% (11/26), "providing information on the behavior-health link" 38% (10/26), "providing information on consequences" 35% (9/26), "modeling or demonstrating behavior" 35% (9/26), "providing feedback on performance" 31% (8/26), and "providing contingent rewards" 31% (8/26).

Furthermore, 80% (12/15) of the studies identified game design elements incorporating gamification features in oral hygiene applications. The most prevalent gamification features were "ideological incentives" 83% (10/12) and "goals" 56% (9/16), found in user-specific and challenge categories, respectively.

Conclusions: Gamification in oral healthcare shows potential as an innovative approach to promote positive health behaviors. Most studies reported evidence-based oral health and incorporated oral healthcare behavior change techniques. Further research is needed to better understand the clinical, psychological, and social factors influencing the selection of effective gamification mechanisms. While the use of mobile health in oral healthcare is still emerging, gamification has proven effective in enhancing individual health-related practices. Clinical Trial: No trial registration.

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Original Manuscript

Title: Gamification and Oral Health in children and adolescents - scoping review

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Abstract

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Furthermore, 80% (12/15) of the studies identified game design elements incorporating gamification features in oral hygiene applications. The most prevalent gamification features were "*ideological incentives*" 83% (10/12) and "*goals*" 56% (9/16), found in user-specific and challenge categories, respectively.

Conclusions: Gamification in oral healthcare shows potential as an innovative approach to promote positive health behaviors. Most studies reported evidence-based oral health and incorporated oral healthcare behavior change techniques. Further research is needed to better understand the clinical, psychological, and social factors influencing the selection of effective gamification mechanisms. While the use of mobile health in oral healthcare is still emerging, gamification has proven effective in enhancing individual health-related practices.

Keywords:

Gamification, Mechanisms of Gamification, Gamification components, Intrinsic and Extrinsic Motivators, Oral Healthcare, Health behavior, Oral healthcare applications.

Background:

People's health behaviors, such as physical activity, diet, tobacco and alcohol use, recreational drug consumption, and adherence to chronic medications, directly influence their health risks, and consequent diseases. To decrease the burden of preventable chronic diseases and enhance well-being in society, it is essential to bring about a change in behavior [1–4]. According to the World Health Organization, oral health is a strong indicator of general health, well-being, and quality of life. The treatment of oral pathologies is expensive and usually not covered under universal healthcare, accounting for 5% of healthcare expenditures and 20% of out-of-pocket expenses in wealthy countries [5–11]. Healthcare systems have limited resources, and making informed decisions based on data collection, focused on individuals, can provide better health outcomes without incurring additional costs - this approach can deliver better value and at the same time reduce costs [12,13].

Motivation is a core target of a wide range of established behavior change techniques [1,14–17]. Computer games can be used to increase health-related knowledge and promote desirable health behaviors in children [18]. Games are designed to provide enjoyment, engagement, and satisfaction [1, 19–22]. Mobile phones and mobile health technologies can address these issues at low costs [1, 23, 24]. Mobile devices are useful for delivering health interventions due to their widespread adoption, powerful technical capabilities, and portability [25]. The positive emotional attachment with the user may increase the benefit of health promotion via mobile devices, allowing health interventions to be delivered immediately, anytime and anywhere [26]. The usage of healthcare applications provides easy access to information and has the potential to improve patient engagement and treatment compliance [27]. Indeed, the number of healthcare applications available has been growing year after year, with over 200 billion app downloads worldwide from the App Store and Google Play in 2020 [28].

Bohn *et al.* found that educational applications are valuable tools for enhancing patient-provider communication in dental settings [29]. Studies have pointed out that the traditional educational approach, which relies mainly on reading and listening to standardized content, should be replaced with customizable and interactive involvement, utilizing communication tools that are familiar to newer generations [30]. Gamification is a possible response to overcoming the challenges of communication and motivation in healthcare [31], as it can track individual behaviors and involve users in goal-chasing activities while displaying progress and feedback through personalized information applications [1,32].

Deterding *et al.* define gamification as the integration of game design elements into non-game contexts [33,34]. This process enriches products, services, and information systems with game-design features to positively influence the motivation, productivity, and behavior of users [34–36]. Gamified systems commonly employ motivational features such as immediate success feedback (reward mechanism), continuous progress feedback, and goal setting. These systems work through interface elements like point-scoring systems, badges, levels, challenges, competitions, relatedness support, social feedback (engagement loops), recognition, comparison through leaderboards, teams, communication functions, autonomized support through customizable avatars and environments, and narratives providing emotional and value-based rationales for certain activities (customization) [1,33,37,38]. Users receive badges that represent success and can be shared in social networks and displayed in a virtual trophy cabinet when new milestones are achieved [35]. Recently, the self-determination theory has become a key framework for health behavior interventions and research [1,39–43]. According to this theory, gamification induces four main intrinsic motivators: user satisfaction, conveyance of optimism, provision of meaning [35,44], and facilitation of social interactions [45,46].

Apart from financial aspects, extrinsic motivators systematically activate intrinsic motivators, such as social recognition, support of learning processes, and behavioral change. The evidence suggests that positive outcomes are stronger when gamification is used to target behavioral outcomes [1,23,24,50–53]. However, critics have pointed out the lack of high-quality effect studies on gamification [22,38,54,55]. Nevertheless, clinicians have an opportunity to promote engagement in health promotion through a motivating, fulfilling, and fun activity [56]. Therefore, this study aims to analyze the impact of gamification and its mechanisms on oral healthcare. This basic review identifies the gamification mechanisms and their outcomes.

Objective: The objective of this scoping review was to analyze the impact of gamification and its mechanisms on oral healthcare in children and adolescents. We assessed the effectiveness of gamification in promoting changes in oral health behavior and enhancing oral healthcare outcomes for its users. Furthermore, we investigated the role of gamification in oral healthcare, including the integration of evidence-based oral healthcare concepts and gamification design elements in applications design.

Methods:

This scoping review aims to analyze the impact and efficiency of gamification mechanisms in oral healthcare, with a focus on promoting user engagement to expand oral health literacy and support oral healthcare policies, in accordance with PRISMA guidelines [57,58].

Scoping review

This review utilized a systematic methodology to identify gamification and oral healthcare applications, evaluate their features, identify their gamification mechanisms, and observe their outcomes.

We did not apply any restrictions related to population samples or oral healthcare systems, but we excluded contexts outside oral health.

The following main questions guided our analysis:

- Does gamification in oral healthcare impact oral health?
- Does oral healthcare gamification enhance health promotion and literacy?

Based on these questions, we searched several domains, including oral healthcare outcomes, gamification design elements, evidence-based oral healthcare concepts used in applications development, and oral health behavior changes related to gamification. We included all studies that reported oral healthcare gamification, identified their gamification mechanisms, and observed their outcomes.

We use PICO to elucidate the systematic review questions:

P - Patient, Population or Problem: the population under investigation included children and adolescents: mother-preschooler (3-6 years old) dyads and adolescents (under 16 years old).

I - Intervention: The intervention under investigation was the gamification strategy and its usefulness for oral health promotion and literacy.

C - Comparison: It was compared the gamification and its alternative, the traditional learning methods.

O - Outcome: The outcome assessed was divided into two main sections: behavior change techniques and gamification mechanisms.

Search strategy

The search was conducted across several electronic bibliographic databases, including Pubmed/Medline, PsycINFO, The Cochrane Library, Science Direct, and Lilacs. In addition, grey literature, conference proceedings, and internet resources WHOQOL were assessed. The search strategy included terms related to gamification and oral healthcare such as gamification, oral

healthcare, policies, games, digital, applications, and outcomes. The authors utilized a controlled and hierarchically organized vocabulary produced by the National Library of Medicine called the Medical Subject Headings to ensure that the search results accurately reflected the subject content of journal articles as they are published. The search strategy enabled us to identify both published and unpublished studies. All sources were last searched until July of 2023, except Pubmed/Medline that was until January of 2023. The references to gamification remotes to nearly 2010. And articles exploring gamification in oral health where only mentioned or studied on the last decade. There were no language restrictions, and studies published between January 2013 and December 2022 (10 years) were included.

The search string used on Pubmed, was: "Gamification" [mh] OR "oral healthcare" [tiab] OR "gamification" [tiab] OR ad tiabl OR "applications"[tiab] OR "gamification"[tiab] OR "digital" [tiab] OR "games"[tiab] OR "outcomes"[mh] OR policies[tiab] OR gamification[tiab] OR "oral health" [(mh:noexp)].

Initially, all types of articles were considered eligible, including systematic reviews, research articles, and prospective and retrospective studies, as long as they met the following criteria: (1) peer-reviewed; (2) full papers; (3) empirical research (qualitative and quantitative); (4) explained research methods; (5) gamification as a research subject; (6) effect reported in terms of impact (affect, behavior, cognition), user experience; and (7) oral healthcare outcomes. Criteria 1-4 were implemented to ensure focus on high-quality work reporting original research. Criteria 3, 4, and 7 were also included to enable assessment of the quality of evidence. Criteria 5 admitted papers that studied gamification in a broader concept, even if it did not elicit game elements. Criteria 6 and 7 were chosen to assess reported health and well-being outcomes and potential mediators, with user experience being included given its prevalence as an outcome.

However, some studies were excluded if they (1) were duplicated; (2) had full text not available; (3) were not the original article; (4) did not refer to a game; (5) were non-digital, such as conventional games like cards or board games; (6) did not concern oral health; (7) were study protocols without outcomes to report.

Study quality assessment, data extraction, and analysis plan

All searched articles were filtered using broad selection criteria framed as questions:

- Does gamification in oral healthcare impact oral health?
- Does oral healthcare gamification enhance health promotion and literacy?

The study selection and data extraction were performed blindly. After the search, all references were imported into a reference management system (Mendeley) and duplicates were removed. The remaining articles' titles and abstracts were assessed to identify eligible studies. To determine eligibility, three additional questions were asked and answered: (1) Is the topic relevant to the defined scope? (2) Does it meet the inclusion and exclusion criteria? and (3) Is the methodology appropriate?

To ensure a comprehensive, transparent, and objective extract process, a standardized pre-piloted form was used to extract data from the included studies.

Two reviewers independently extracted the data, and any discrepancies were resolved through discussion with a third author.

Additionally, the third reviewer further scrutinized the data to verify the consistency of the extraction process and resolved any remaining discrepancies. In case of missing or additional data, other researchers were contacted [59, 60].

The eligibility assessment of each full-text was conducted by two independent raters. In cases where discrepancies arose, they were resolved through discussion and comparison of our evaluations. Articles were excluded from our review when both investigators unanimously concurred on their ineligibility due to inappropriate methodology or results that did not address the key research questions at hand. This rigorous and collaborative approach to eligibility assessment ensured the quality and relevance of the articles included in our study.

Each article was classified as having low, moderate, or high relevance. Articles were deemed highly relevant if they effectively demonstrated impact on the considered items, while moderate relevance was attributed to those that projected such items. Low relevance was assigned to manuscripts that did not present any conclusions or perspectives in these domains.

Data from the scoping literature were extracted into an electronic Excel data sheet using a support checklist. The data sheet was divided into sections dedicated to a theory, area, concept, theme, or element from the framework of gamification and oral healthcare, including game mode, population sample, gamification components, behavior change techniques, and outcomes. After synthesizing the data and assessing the quality of the evidence, the writing of the scoping review article began.

Results

Process selection

Figure 1 shows the PRISMA flowchart outlining the process of record identification, selection, eligibility, and inclusion. Initially, 617 records were retrieved from five databases and grey literature sources. After removing duplicates and records that did not meet the inclusion criteria, 15 records were selected for analysis.

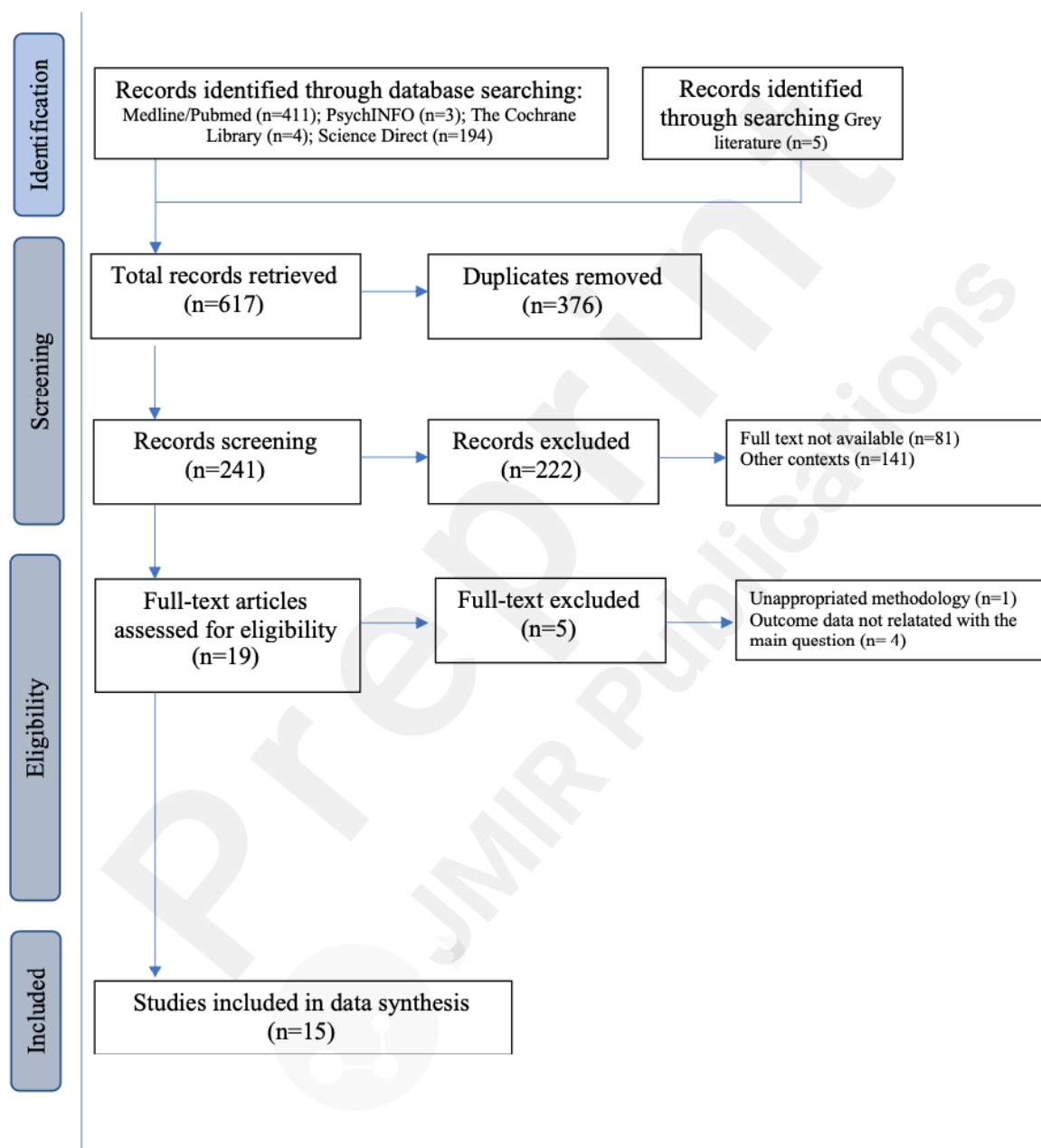


Figure 1. PRISMA flow diagram.

Sample characteristics

Of the fifteen studies available, the majority (8/15, 53%) collected data at multiple timepoints (two or more) from various points or conditions [18,30,61-66]. Seven out of these eight studies were blind, randomized control trials [18,30,62,63,65,66,67]. A content analysis of the applications for

behavior change was adopted in seven studies [9,27,64,65,66,68,69]. One-time cross-sectional questionnaires were applied in three studies [26,70,71].

The sample size in the selected studies ranged from 34 to 190 individuals. All subjects were children under 13 years old, except for four studies that also included adults [26,65,66,69]. Mobile applications were the predominant modality used to change oral healthcare behavior in the studies (n=12), with three exceptions based on computer games. One of the games was available on a tablet and DVD for PC [72], while the other two applications were associated with a toothbrush sensor [62,63].

Oral hygiene evidence based categories

The oral self-care application supported by evidence-based oral health was mentioned in 73% of the selected studies (11/15). The group categories and archetypes of evidence-based content related to oral hygiene were identified by analyzing the selected studies, as illustrated in Figure 2

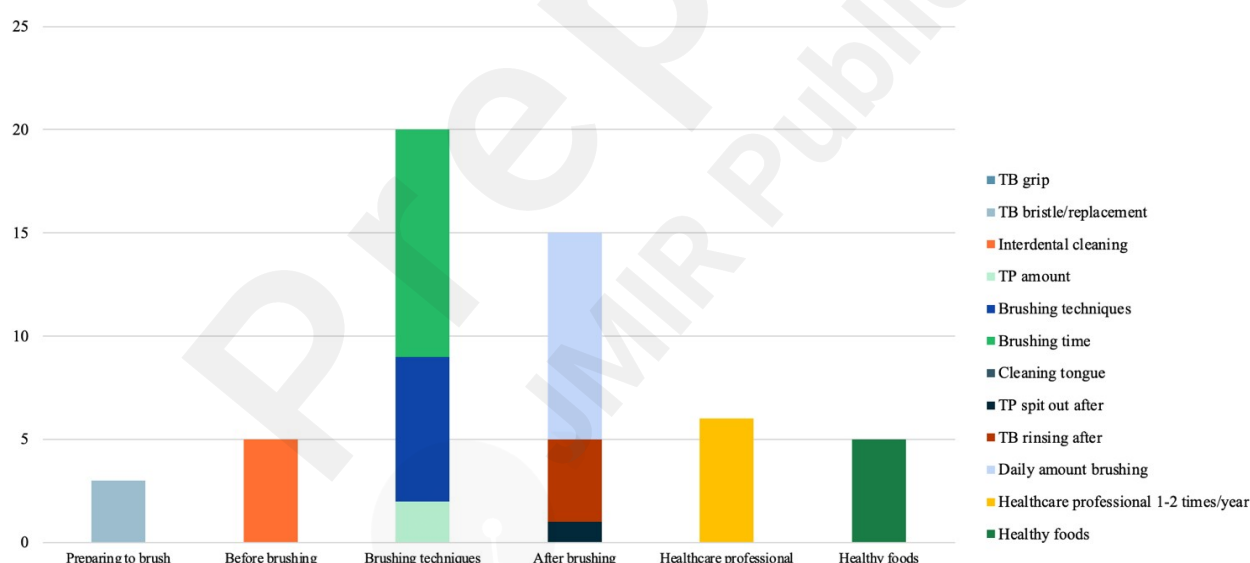


Figure 2. Evidence-based content related to group categories and archetypes of oral hygiene, as recognized in the chosen studies. The y-axis displays the listed group categories and archetypes, while the x-axis signifies the frequency of their occurrence within the studies. The accompanying legend elucidates the color-coding system denoting distinct group categories and archetypes. Abbreviations include TB for toothbrush and TP for toothpaste.

We found that the most clearly defined types of information in the applications were “brushing time” for at least 2 minutes 100% (11/11) and “daily amount brushing”, at least twice a day 91% (10/11). However, “toothpaste spit out after” brushing was only found in one application 8% (1/12), and “cleaning the tongue” and “toothbrush grip” were never mentioned.

Behaviour change techniques

Behavior change techniques for oral healthcare resulted from mechanisms of gamification, either implicit or explicit. Oral healthcare behavior change techniques was mentioned in 73% (11/15) of the studies. The data collected from these studies were used to create a behavior change score with 26 items [9]. The studies were analyzed to determine the frequency of behavior change techniques utilized in oral health applications, as shown in Table 1

Table 1. Frequency distribution of behavior change techniques observed in oral health applications identified in the selected studies.

Behavior changes techniques	Frequency (%)
1. Provide information behavior health link	10/137 (7.3)
2. Provide information on consequences	8/137 (6.6)
3. Provide information other's approval	1/137 (0.7)
4. Prompt intention formation	11/137 (8.0)
5. Prompt barrier identification	3/137 (2.2)
6. Provide general encouragement	7/137 (5.1)
7. Set graded tasks	2/137 (1.5)
8. Provide instruction	11/137 (8.0)
9. Model or demonstrate behavior	9/137 (6.6)
10. Prompt specific goal setting	4/137 (2.9)
11. Prompt review of the behavioral goals	5/137 (3.6)
12. Prompt self-monitoring behavior	2/137 (1.5)
13. Provide feedback on performance	8/137 (5.8)
14. Provide contingent rewards	8/137 (5.8)
15. Teach to use prompts or cues	4/137 (2.9)
16. Agree on behavioral contract	7/137 (5.1)
17. Prompt practice	7/137 (5.1)

18. Use follow-up prompts	4/137 (2.9)
19. Provide social comparison	2/137 (1.5)
20. Plan social support or change	2/137 (1.5)
21. Prompt identification as role model	2/137 (1.5)
22. Prompt self-talk	2/137 (1.5)
23. Relapse prevention	4/137 (2.9)
24. Stress management	1/137 (0.7)
25. Motivational interviewing	5/137 (3.6)
26. Time management	7/137 (5.1)

Among the behavior change techniques scrutinized, a set of seven distinct components emerged as the most prevalently employed across the array of surveyed studies. These components, along with their respective frequencies of utilization, are outlined as follows: “prompt intention formation” 42% (11/26), “provide instructions” 42% (11/26), “provide information on behavior-health link” 38% (10/26), “provide information on consequences” 35% (9/26), “model or demonstrate behavior” 35% (9/26), “provide feedback on performance” 31% (8/26), and “provide contingent rewards” 31% (8/26).

Gamification mechanisms

The game design elements based on the gamification features rating criteria for oral hygiene applications were recognized in 12 out of 15 studies (80%). Table 2 illustrates the 26 gamification features [9] that were considered, along with the number of times each element was identified.

Table 2. Frequency distribution of game design elements detected in the surveyed studies.

Game design elements		Frequency (%)
System Design	Visual Feedback	9/36 (25.0)
	Audible Feedback	4/36 (11.1)
	Reminder	5/36 (13.9)
	Meaning	10/36 (27.8)
	Integration Concepts	3/36 (8.3)
	Visually resembling games	1/36 (2.8)
	Fantasy	4/36 (11.1)
Challenges	Goals	9/16 (56.3)
	Time pressure	4/16 (25.0)
	Progressive disclosure	3/16 (18.8)

Rewards	Ownership	9/22 (40.9)
	Achievement	5/22 (22.7)
	Point System	4/22 (18.2)
	Badges	0/22 (0)
	Bonus	4/22 (18.2)
Social Influences	Loss Aversion	2/19 (10.5)
	Status	2/19 (10.5)
	Collaboration	3/19 (15.8)
	Reputation	3/19 (15.8)
	Competition	1/19 (5.3)
	Envy	1/19 (5.3)
	Shadowing	2/19 (10.5)
	Social Facilitation	2/19 (10.5)
	Conforming Behavior	0/19 (0)
	Leaderboards	2/19 (10.5)
	Altruism	1/19 (5.3)
	Virtual Goods	0/19 (0)
User Specifics	User Levels	1/12 (8.3)
	Ideological Incentives	10/12 (83.3)
	Virtual Characters	1/12 (8.3)
	Self Expression	0/12 (0)

On average, the applications included in the study possessed an average of 10.6 out of 31 potential gamification features. Notably, specific game design elements were prevalently employed within various categories. Among the system design features, "meaning" 28% (10/36) stood out prominently. Within the challenges category, "goals" 56% (9/16) emerged as the most frequently incorporated element. For rewards, "ownership" 41% (9/22) was notably prevalent. Among social influences, both "collaboration" and "reputation" 16% (both, 3/19) were prominent. Additionally, within the user specifics category, "ideological incentives" 83% (10/12) exhibited a substantial presence. Interestingly, none of the applications utilized "badges", "conforming behavior", "virtual goods", or "self-expression" Table 2.

Discussion

Principal Findings

The oral health outcomes related to gamification interventions highlighted the role of gamification in promoting oral health care and literacy. This scoping review also highlights the limitations of currently available oral healthcare applications and points out the main areas to invest in for the future.

Eleven out of fifteen articles found positive impacts of using oral health applications, especially in children and adolescents. They facilitate the responsiveness of oral preventive care [70], improve knowledge in high-risk populations, encourage dietary changes [67], and promote reduction of clinical plaque, gingival, and caries indexes [26]. Additionally, they show statistically significant improvement in healthcare indices [62], tooth brushing quality (duration and distribution) [64], motivation to brush teeth for longer [26], and seem effective in adolescents with fixed orthodontic appliances by self-reported behavior and psychosocial factors [63]. Gamification structures augment oral health literacy, facilitate user alertness for oral healthcare themes and professional feedback, and engage commitment. A greater improvement in gingival status is commonly reported [27,65,66,73].

The feedback provided by participants showed a higher level of satisfaction in learning about oral healthcare through games rather than traditional non-interactive methods. Most studies reported a positive impact of gamification, particularly in children and adolescents, who are considered the main target audience of these applications [18,26,30,62,63,64, 65,66,67,68,69,70].

The studied applications contained educational content with evidence-based dentistry and high-quality teaching for oral self-care. Some of these applications also feature gamification elements and behavior change techniques. The results of the studies demonstrate that these applications have excellent functionality, effectiveness, efficiency, and user satisfaction [9,68,70]. Several studies evaluating multiple oral hygiene applications have found evidence-based content, such as brushing time and daily amount of brushing. Fijacko *et al.*, Parker *et al.*, and Hotwani *et al.* all reported on these elements [9,27,68].

The health behavior changes techniques found in the analyzed applications included prompt intention formation, shaping and demonstrating behavior, providing information about the link between behavior and health consequences, instructions, and contingent rewards. [26,30,62,67,70,71]. A set of seven distinct components emerged as the most prevalently employed across the array of surveyed studies. These components, along with their respective frequencies of utilization, are outlined as follows: “prompt intention formation”, “provide instructions”, “provide information on behavior-health link”, “provide information on consequences”, “model or demonstrate behavior”, “provide feedback on performance”, “provide contingent rewards”. These components collectively represent the core elements of behavior changes techniques that were consistently integrated into the analyzed oral health applications, aiming to enhance engagement and promote positive behavior change.

Regarding game design elements, these applications emphasized feedback, goal attainment, sense of ownership, and ideological incentives [27,65,69,70,71]. Parker *et al.* identified some recurring game design elements among twenty applications analyzed, such as knowledge provision, self-monitoring of frequency and duration of toothbrushing [27]. Hotwani *et al.* found that information provision, goal setting, feedback, progressive disclosure, and time pressure were frequently used in the six applications evaluated [68]. Fijacko *et al.* analyzed seventeen applications and identified time pressure, virtual characters, and fantasy as key game design elements [9].

Comparison to Prior Work

Delivering trustworthy information to users is essential for promoting healthy habits. Healthcare applications should undergo validation by healthcare institutions and professionals before becoming public to ensure their accuracy and reliability. However, there is a risk of users becoming overly dependent on these applications, potentially compromising the need for regular appointments with oral healthcare professionals in real life [27,79].

Considering evidence-based oral healthcare, most applications emphasize brushing for at least two minutes and twice a day. While this is an important core of oral hygiene recommendations, there is still room for improvement. To achieve holistic oral care, it would be advisable to incorporate other aspects such as oral hygiene techniques, the use of devices, dietary advice, sugar intake control, guidance on early childhood caries, baby oral hygiene, the effects of fluoride, the use of fluoride toothpaste, tooth-brushing training videos, and regular dental visits. The development of applications should be based on theoretical models when designing educational content, and the accuracy of the content should be a priority to bring about real behavior change [65,68,79]. Sharif and Alkadhimi went beyond the basics and included interdental-cleaning, spitting out after brushing, avoiding mouth rinsing after brushing, characteristics of the toothbrush, and the quantity of fluoride content in toothpaste and mouthwash [80]. Other advisable strategies include reporting about others' approval, social interactions with oral health professionals and other application users, identifying barriers to oral hygiene and potential overcoming strategies, providing encouragement, setting graded tasks and goals, displaying tracked data and objectives, feedback on performance, setting a behavioral contract with oral health professionals, social comparison, and social support [1,9,27,35,67,78,80].

Patient adherence to a smartphone application is more effective because of the ability to customize reminders and prompts, constant accessibility, adjustability to the user, ability to provide tailored feedback, widespread use, and interactive features [67,81,82].

Strengths and Limitations

Despite the proven efficiency of gamification in healthcare promotion and prevention, it remains an unexplored territory in oral health, mainly applied to specific educational purposes and oral health promotion. [76]. This scoping review highlights the limitations of currently available oral healthcare applications and points out the main areas to invest in for the future.

Two major limitations were found in the present study. First, the limited availability of articles related to the main topics. Gamification, within the context of healthcare, is not a recent concept. However, its quantitative assessment, particularly in the field of oral health, remains relatively uncommon. However, to address such limitation and ensure a comprehensive review, we diligently accessed and explored five databases, along with incorporating grey literature sources. This approach was essential to include as many relevant studies as possible, aligning with our predefined inclusion criteria. Considering the diverse nature of our search strategy, we believe we have made every effort to provide a reliable representation of the existing literature in the field of gamification in oral healthcare.

Second, the heterogeneous studies with varying focus and dispersing attention. We acknowledge your observation that, despite the inclusion of relevant studies, there were some interesting works that unfortunately did not meet our stringent inclusion criteria. This, in turn, may have resulted in a limitation in the number of studies analyzed in our research. The diversity of approaches makes a rigorous comparison more challenging.

We are fully aware of the importance of identifying and adhering to precise parameters associated with quantifying the results of studies, particularly within the context of gamification. Taking into account the multiple aspects involved in gamification strategies and by transparently outlining these parameters, we believe our work can serve as a valuable reference for future researchers seeking to design studies that address and overcome these challenges. Our hope is that this will pave the way for a more effective understanding of the underlying mechanisms behind the implementation of gamification in oral health context.

Future Directions

Future studies could focus on other age groups as well, such as the study by Zolfaghari *et al.*, which developed applications for mothers of children, improving their oral health literacy and practice, and promoting plaque control in children within just one month of utilization [65,75,76].

There is potential for future optimization of key gamification features, such as badges, encouragement of correct behavior, virtual goods, self-expression, reminders, fantasy themes, time

pressure, disclosure of progress, achievements, points systems, bonuses, loss aversion, status, collaboration, reputation, competition, shadowing, social facilitation, leaderboards, altruism, user levels, and virtual characters [26,27,30,70,77,78].

Conclusion:

Gamification in oral healthcare does has an impact and the utilization of oral healthcare gamification enhance oral health promotion and literacy. Gamification in oral healthcare represents a potential new approach for oral healthcare providers to change people's oral health behavior. The most frequent game design mechanisms adopted were meaning, ideological incentives, feedback, goals, and ownership. Some authors have highlighted several factors for gamification success, including engagement strategy, applications aesthetics, evidence-based information content, behavioral change taxonomies, attention to psychological needs, evaluation, validation, quality assessment, and professional regulation standards for oral healthcare applications. More studies are needed to better understand the clinical, psychological, and social processes involved in selecting the most efficient gamification mechanisms. The process of mobile health in oral healthcare is in the initial stage, but gamification in oral healthcare is crucial for improving individual health-related practices.

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Conflicts of interest:

Nothing to declare.

Multimedia Appendix 1

Full paper details

PMID Author	Game Mode	Population sample	Gamification components	Oral hygiene categories	Behavior changes techniques	Outcomes
Paper 1 [70] Ito <i>et al</i> , 2013	Serious game	Children 115 children 3-6y CSQ	Goal: tooth remains whole. Evaluation of avatar oral state		Evaluate the advantages of decision making	Facilitate the awareness of preventive dental care for children aged 3 to 6 years
Paper 2 [18] Panic <i>et al</i> , 2014	Interactiv e game	Children 190 children 7-9y BRCT	Scores: removing residues. Avatar Beaver Ben teach. Threat weak/strong. Questionnaire. Snack reward (unhealthy/healthy)	Info oral hygiene; Brushing teeth properly. Dentist 2xyear. Healthy foods.		Threat message + health information; medium which information is presented influences the effectiveness of the message. Games may not always be the most effective medium to reinforce a strong threat appeal
Paper 3 [26] Underwood <i>et al</i> , 2015	App 'Brush DJ'	Children and adults 189 responds CSQ	Quiz motivate users to brush for two minutes by playing music. Reminder: brush, appointments Information: oral hygiene	Floss and interdental brushes before. Brushing teeth for 2 min, twice a day. brush different parts of the mouth visually, by vibration and sound after 30''; not rinse after. mouthwash at different time appointments. Change toothbrush 3 months. Video tutorials.	Instructions and Demonstration: animated videos. Prompts: interdental before brushing, not rinse after. Cues: brush different parts visually, vibration and sound after 30'' Social reward: share via social media the name of the song that have listen. Other reward: smile and applause with 2 min brushing	70% of their teeth felt cleaner. 80% motivated to brush their teeth for longer. 92.3% would recommend the app to their friends and family. How the app helped toothbrushing: motivation, education, compliance, and perceived benefit
PMID Author	Game Mode	Population sample	Gamification components	Oral hygiene EB categories	Behavior changes techniques	Outcomes
Paper 4 [30] Zotti <i>et al</i> , 2016	App 'Brush Game'	Children 80 adolescents with multibrackets Mean age: 14.1y Duration: 1 year BRCT	WhatsApp competit 2 selfies(b/a)/week. Nickname; reminder Rank: best 5/week Score: plaque index, gingival index, white spots, caries Social motivation Share information. Share videos	Video tutorials. Brush teeth. Oral hygiene kit: toothpaste, toothbrush, mouthwash, interproximal brush, dental floss, plaque disclosing tablets	NA	Significantly lower values of both plaque and gingival indexes; lower incidence of new white spots and caries, compared with the control group.

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Supplementary Files

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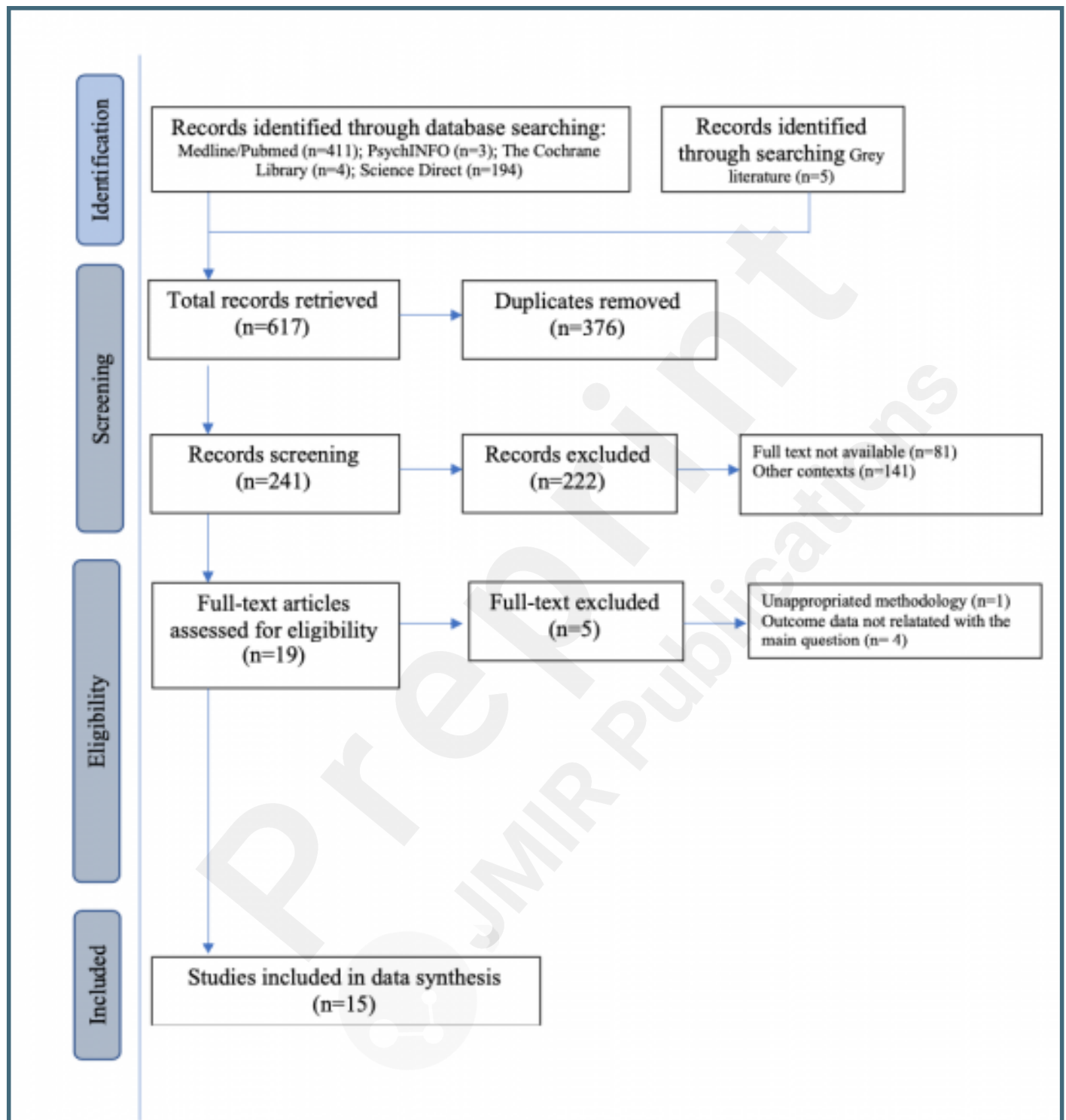
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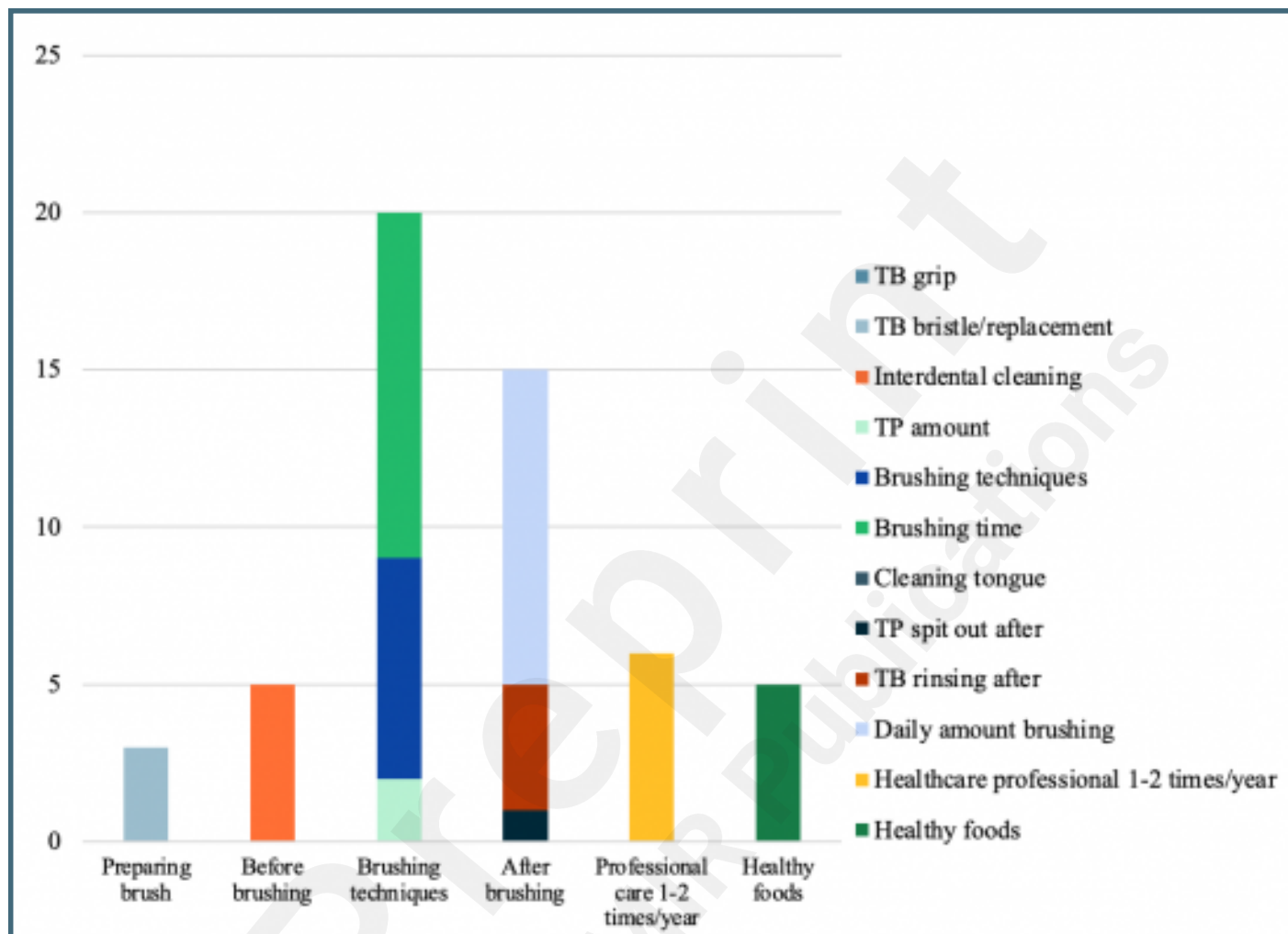
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Figures

PRISMA flow diagram.



Evidence-based content related to group categories and archetypes of oral hygiene, as recognized in the chosen studies. The y-axis displays the listed group categories and archetypes, while the x-axis signifies the frequency of their occurrence within the studies. The accompanying legend elucidates the color-coding system denoting distinct group categories and archetypes. Abbreviations include TB for toothbrush and TP for toothpaste.



Multimedia Appendixes

Full paper details.

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