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Current State of Serious Games in Dentistry: A Scoping Review

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Abstract

Objective: Over the past decade, serious games (SGs) have played a growing role in medical education and health promotion; however, little is known about their use in the field of oral health. This study provides a comprehensive synthesis about SGs developed for training oral health professionals or for health promotion in oral health.
Material and Methods: A systematic search was conducted. The following electronic databases were reviewed: MEDLINE (1966 to September 2019), Embase (1980 to September 2019), and Cochrane Central Register of Controlled Trials (CENTRAL), LILACS and Scopus from inception to September 2019. Two reviewers independently screened and assessed the study's quality and extracted data. The Sardi and collaborators' tool was used to assess the quality of the evidence presented.
Results: A total of 19 studies (25 articles) were selected. Games were divided into two categories: for specific educational purposes and for oral health promotion. Most studies involved oral health professions' students ($n=9$) or school/preschool children ($n=9$). Two studies included preschool children and parents. Interactive SGs were as effective as traditional noninteractive methods in improving oral health outcomes. Nonetheless, participants' feedback reflected a higher level of satisfaction in learning through games. The quality of the studies was limited due to the lack of a proper technical description of the games and the absence of discussion of the limitations and challenges of the games.
Conclusion: The use of SGs in oral health is limited, and little valid empirical evidence is available to confirm their effectiveness. Further studies are required for using more rigorous designs, evaluation, and follow-ups.

Keywords: Oral Health, Serious games, Scoping review

Introduction

Over the past decade, serious games (SGs) have become highly relevant in the fields of medical education and health promotion.[1] SGs are a form of game-play with specific learning aims. They have been defined as ''interactive computer application, with or without significant hardware component, that has a challenging goal, is fun to play and engaging, incorporates some scoring mechanism, and supplies the user with skills, knowledge or attitudes useful in reality.''[2] SGs are designed to complement education-based content with gameplay, providing users with the capability to apply specific learning outcomes to the real world. In game-based learning a player engages in the game's activity and loses the sense of effort and repetition, and gains knowledge and satisfaction from solving the game's challenges. Motivation and engagement are fundamental elements to framing learning from gaming experience.[3]

Due to their engaging and entertaining aspects, such as competitive and feedback elements, learning through SGs has become an increasingly popular approach to medical education, health promotion, and disease prevention.[4] When playing a game, players are motivated to keep on playing to reach the game's objective. Repeated attempts to achieve this goal stimulate the brain, promoting knowledge acquisition and skills development.[5]

The SGs created for training purposes have been shown to be as effective as conventional methods, in improving both the knowledge of medical students and health professionals and as a complement to traditional learning methods.[1] There is also a preference for learning through interactive games rather than through a conventional method.[6] Adults tend to learn based on their experiences; therefore, a more enjoyable learning process may improve motivation for proactive learning.[5] A recent systematic review found that medical educators prefer simulations

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and quizzes focused on knowledge retention and skill development through repetition, over more sophisticated games.[7] However, games developed for this purpose may require further, more rigorous evaluation and follow-up.[8]

In the context of health promotion programs, SG have been found to be effective in the prevention or treatment of diverse areas, such as diabetes, asthma, cancer, mental health and among different populations, both children and adults.[9] A systematic review[10] assessed whether SGs are useful in improving health outcomes and showed that SGs have the potential to improve health outcomes, particularly in the areas of psychological therapy and physical therapy. However, this review found that most studies were of low quality and more rigorous randomized controlled trials are needed. The changes in health outcomes through SGs are achieved via the provision of health-related information, modeling of positive health behaviors, or the creation of opportunities to practice healthy lifestyle skills.[11]

There is a consensus that the application of SG approaches provides an accessible source of new information, as most people these days have access to a computer and mobile technology. Moreover, these technologies do not require higher levels of education to operate, therefore, they allow learning improvements independent of age and educational background.[12,13] Although initial development of SG can be costly, they are relatively cheap to run and they may ultimately drive significant advancements in oral health knowledge and learning and oral health promotion. The SGs in oral health comprise an emerging area and little is known about their current uses and potential.

Thus, the aim of this scoping review is to provide a comprehensive synthesis on the use of SGs that have been developed in the oral health field. By identifying current practice, assessing the design of studies included in the review and their theoretical base, we aim at contributing to a better understanding of the factors that determine successful (or failed) SG adoption in the oral health field.

Methods

This scoping review was reported according to Preferred Reporting Items for Systematic reviews and Meta-Analyses extension for Scoping Reviews (PRISMA-ScR) guidelines.[14]

To obtain a detailed view on the use of SG in dentistry, the following research questions and specific objectives listed in Table 1 were developed. We included primary studies and conference papers focused on the use of SGs in dentistry, published in English, Spanish, and Portuguese. Papers that described a prototype, evaluating the application or the impact of an SG for education or health promotion in the oral health field, were also included. We excluded secondary studies or those published in the form of abstracts, tutorials, or posters.

Sources of information and search strategy

A systematic search of the literature was conducted by using the following electronic databases: MEDLINE (1966 to September 2019), Embase (1980 to September 2019), and Cochrane Central Register of Controlled Trials (CENTRAL), LILACS and Scopus from inception to September 2019.

Reference listings of selected articles and previous systematic reviews were hand searched to identify other possible studies. The details of the search strategy used are given in Table 2.

Study selection and data extraction

All references identified were extracted to an EndNote X9 database to facilitate their management, and duplicate articles were eliminated.

Titles and abstracts of studies retrieved by using the search strategy were screened independently by two review authors (C.Z. and C.A.-A.) to identify studies that potentially met the inclusion criteria. We obtained the full text of all relevant and potentially relevant studies, those appearing to meet the inclusion criteria, and those for which there are insufficient data in the title and abstract to make a clear decision. Further, only studies that fulfilled all the eligibility criteria were included. Any disagreement between the two review authors over the eligibility of studies was resolved through discussion with a third reviewer (R.M.). The authors extracted the following information from each article by using a standardized, predefined data collection form: author, year, aims of studies reviewed (education or promotion), study design, theoretical model, setting, target group, details of SG, main results, and authors' conclusion.

Table 1. Research Questions

Research question	*Specific objective*
1. How is the research focused on serious game in dentistry distributed?	Explore the temporal and geographical relationship and the setting in which studies on serious games have been developed
2. What are the design types of the studies related to serious games in dentistry?	To identify the main types design used in studies on serious games in dentistry
3. What are the purposes and topics for which serious games in dentistry are developed?	To identify purpose and topics most frequently investigated in the studies about serious games in dentistry
4. What are the game elements used in the serious games in dentistry?	To identify the main mechanics used to develop serious games in dentistry
5. What is the methodological quality of the reports about serious games in dentistry?	To analyze the methodological quality of the included studies
6. What is the theory behind the design of the serious games in dentistry?	To describe the theoretical perspective used to develop the serious games in dentistry
7. What is the effectiveness of serious games in dentistry?	To summarize the effectiveness of serious game in dentistry?

Table 2. Search Strategy Used in Each Database

Source	*Strategy*
Medline	(((((((game-based) OR ''Games, Experimental''[Mesh]) OR ''Video Games''[Mesh]) OR ((((game*) OR gaming)) AND (((((((video) OR serious) OR digital) OR educational) OR web) OR learning) OR online) OR training)))) AND ((((''Oral Health''[Mesh]) OR oral health) OR dentist*) OR dental)))
Embase	#21. #16 AND # 20 #20. #17 OR #18 OR #19 #19. oral AND health #18. dentist* #17. dental #16. #4 OR #5 OR #15 #15. #3 AND #14 #14. #6 OR #7 OR #8 OR #9 OR #10 OR #11 OR #12 OR #13 #13. training #12. online #11. learning #10. web #9. educational #8. digital #7. serious #6. video #5. 'video game'/exp #4. 'game based' #3. #1 OR #2 #2. gaming #1. game*
Scopus	TITLE-ABS (game* OR gaming) AND TITLE-ABS (video OR serious OR digital OR educational OR web OR learning OR online OR training) AND TITLE-ABS (''oral health'' OR dentist* OR dental)
Lilacs	(game$ OR gaming) AND (video OR serious OR digital OR educational OR web OR learning OR online OR training) AND (MH:''oral health'' OR dentist$ OR dental)
Cochrane Central	#18. #17 AND # 16 #17. #3 AND # 12 #16. #13 OR #14 OR #15 #15. (oral health):ti,ab,tw #14. (dentist*):ti,ab,tw #13. (dental):ti,ab,tw #12. #4 OR #5 OR #6 OR #7 OR #8 OR #9 OR #10 OR #11 #11. (training):ti,ab,tw #10. (online):ti,ab,tw #9. (learning):ti,ab,tw #8. (web):ti,ab,tw #7. (educational):ti,ab,tw #6. (digital):ti,ab,tw #5. (serious):ti,ab,tw #4. (video):ti,ab,tw #3. #1 OR #2 #2. (gaming):ti,ab,tw #1. (game*):ti,ab,tw

Critical appraisal

Two investigators (C.Z. and C.A.-A.) independently analyzed the quality of the reports of the included articles, employing a checklist previously developed to assess articles about gamification, which was adapted for the objectives of this study.[15] The quality assessment checklist is shown in Table 3. Question QA1 scores partially when the paper does not provide details about the game elements employed in the application. QA5 is rated by analyzing the CORE Conference Ranking Exercise 2018 (http://portal.core.edu.au/conf-ranks) and the Journal Citation Reports (JCRs) 2018 (https://jcr.clarivate.com). The sum of scores of each question provided an overall assessment score for each study, with a range of 0 to 6. Discrepancies between reviewers were also resolved by a third reviewer (R.M.).

Finally, the results were synthetized following Green et al. recommendations.[16] A narrative overview model, which is a broad narrative synthesis of formerly published studies, was constructed. Studies were grouped by type of purpose. Formal ethical approval is not required as no primary data will be collected. All information is freely available in the public domain.

Results

The search identified 923 citations. After 253 duplicates were excluded, 670 titles and abstracts were reviewed, and 40 articles were fully read. Of the full-text articles reviewed, 11 were excluded because they were not SGs, 6 were not SGs in dentistry, 3 were secondary studies, and 1 paper was in French language.[3,17–36] In addition, six studies were identified by

Table 3. Report Quality Assessment Checklist

No.	Quality assessment question	Answer
QA1	Does the paper present a detailed description of the game elements employed?	(+1) Yes (+0) No (+0.5) Partially
QA2	Does the study present empirical results?	(+1) Yes (+0) No
QA3	Are the limitations of the serious games addressed explicitly?	(+1) Yes (+0) No
QA4	Does the paper discuss the benefits of the serious games?	(+1) Yes (+0) No
QA5	Has the study been published in a relevant journal or conference proceedings?	For conferences, workshops, and symposia: (+1.5) if it is ranked CORE A (+1) If it is ranked CORE B (+0.5) If it is ranked CORE C (+0) If it is not in the CORE ranking For journals: (+2) If it is ranked Q1 (+1.5) If it is ranked Q2 (+1) If it is ranked Q3 or Q4 (+0) if it has no JCR ranking For others: (+0).

JCR, Journal Citation Reports.

hand search. Finally, 25 articles,[6,12,37–53] corresponding to 19 studies, were included, because six studies were reported more than once.[54–59] Figure 1 shows the flow diagram of the selection process of our review. The main characteristics of the included studies are presented in Table 4.

RQ1: How is the research focused on SG in dentistry distributed?

The included studies were published between 2008 and 2019, with the majority ($n=13$) conducted in or after 2013. The year 2017 was the peak year.

About half of the SGs ($n=9$) were developed in Brazil,[12,38,39,41,44,47–50] three in the United Kingdom,[43,51,52] two in Taiwan,[37,45] and two in the United States.[6,53] A smaller number ($n=1$) were developed in Germany,[46] Spain,[42] and South Africa.[40] Regarding the setting for the games, the largest group of them took place in universities or dental schools ($n=9$); followed by preschools or schools ($n=6$), health centers or hospitals ($n=3$), and home ($n=1$).

RQ2: What are the design types of the studies related to SGs in dentistry?

According to the design of the study, most of them used either qualitative ($n=8$) or quasi-experimental designs ($n=6$). Three had true experimental designs (randomized clinical trial [RCT]). In addition, two studies only presented a description of the prototype without reporting any kind of assessment. The qualitative studies were expert or users' technical evaluations of the prototype. For experimental and quasi-experimental designs, follow-ups were generally short (up to 3 months) and only the study of Jacobson et al.[53] had a follow-up period of 1 year. The number of participants involved in the evaluation process ranged from 10 to 109. The randomized control trials included larger numbers of participants ($n=80$–109).

RQ3: What are the purposes and topics for which SGs in dentistry are developed?

Overall, SGs were designed with varying objectives (i.e., knowledge and skills acquisition), and we identified two main categories: learning aids for specific educational purposes that involved oral health professions' students or professionals; and oral health promotion. Nine SGs were available as learning aids to train undergraduate oral health students. One SG also targeted oral health professionals. The topics included: improvements in clinical knowledge and practical skills to perform suitable Dentin Bonding,[6] dental casting techniques,[37] dental prothesis,[39] and anesthetic procedure based on the haptic interface[41]; two studies[40,42] focused on the morphology of the teeth. Two SGs were developed to teach about biosafety in dentistry[38,44]; another one was developed as an e-learning Dental Public Health resource for dental undergraduates.[43]

Ten SGs were developed for oral health promotion; of these, five were designed for school children,[46,48,50,52,53] three for preschool children,[12,45,49] and two for both preschool children and parents.[47,51] The topics included dental caries prevention,[11,47,48] diet,[11,38,47,49,50] oral hygiene,[12,45–47,50,51,53] other oral health habits,[12,48] dental eruption, and dentition.[47] Huntington et al.[52] developed an SG for children and their families (parents or caregivers) to reduce perioperative anxiety and improve children's behavior and acceptance of procedures, among children who would undergo a tooth extraction under general anesthesia.

RQ4: What are the devices and game elements used in the SGs in dentistry?

Eleven games were developed for computer devices, three for mobile devices, and two for both types of devices. One game was developed for console use (Wii), Haptic and Microsoft Kinect©. One study[49] did not report the type of devices used.

The game design elements varied. For dental education games they used mainly the quiz as a playful strategy (5/9).

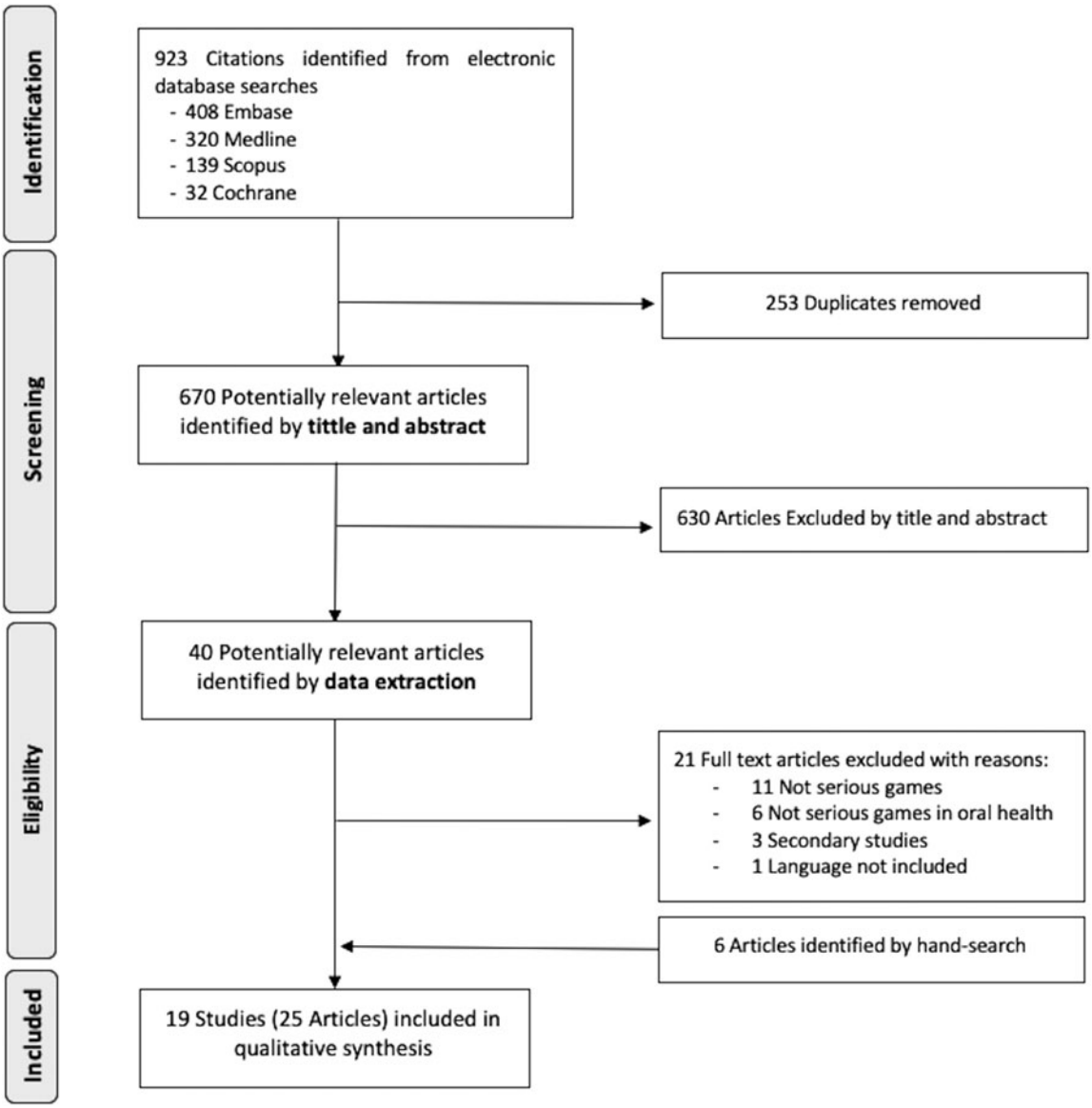

FIG. 1. Flow diagram of the scoping review.

These games included different levels of complexity; however, a few reported incorporating rewards, feedback, sound effects, or players rankings as motivational strategies.[38,41,43,44] Rodríguez-Andrés et al.[42] used autostereoscopy, a method of displaying images in three dimensions, as the main element.

Some SGs developed for oral health promotion used personalized avatars to represent the players. Also, they used the scores, rankings, levels of difficulty, and feedback as motivational strategies.

Wiimote was incorporated in some games to facilitate the interaction of the avatar.[46]

None of the studies included the social interaction to encourage playability.

RQ5: What is the methodological quality of the reports about SGs in dentistry?

Report' quality assessment scores ranged from 1 to 5 with a mean of 2.7 (standard deviation 1.2). None of the studies reviewed obtained the highest possible score of 6. One study obtained five points, and about two-thirds (63.2%) scored 3 or less. The main limitations to obtaining the maximum score were the lack of the provision of a proper technical description of the game and the absence of a discussion of the limitations and challenges of the game, which may affect the games' use, implementation, function, and/or operation. Among the few limitations reported was the difficulty of adapting SG for preschool children due to their short span of attention, inability to adapt to new situations, and lack of ability regarding abstract thinking and understanding of the assessed concepts.[12] Another limitation reported in some studies was the difficulty of assessing knowledge retention after a longer period.[46]

Seven studies did not provide technical descriptions or provided only poor technical descriptions. Eight studies did not present empirical results since they were prototype reports or technical evaluations. One of the questions in the instrument asked about the JCRs ranking of the targeted journal or

Table 4. Characteristics of the Included Studies

References	*Country*	*Study design*	*Topics*	*Setting*	*Theoretical model specified*	*Target group*	*Device (game elements)*	*Description of the SG*	*Main results*	*Quality study assessment*
Dental education										
Yang et al.[37]	Taiwan	Prototype description	Dental casting procedure	University	Yes Game based learning	Undergraduate dental students	Computer (Quiz, training simulation)	This game offers two modes, namely the Dental Casting Game and Dental Casting Question Game. The first mode helps to strengthen the learner's operating skills in dental lost-wax casting through game play, whereas the second mode helps to expand the learner's basic knowledge in dental casting through the question game.	N/A	1
Amer et al.[6]	United States	RCT	Clinical training (dentine bonding)	University	Yes Not clearly explicit	Undergraduate dental students	Computer (Quiz, training simulation)	Interactive dental videogame using Adobe Flash CS3 software to teach the sequencing steps of applying a three-step resin bonding system as used in the operative dentistry curriculum.	There was no statistically significant difference between SG* and watch a clinical video recording in regard to change in either knowledge or clinical skills. Students expressed their preference for the use of the SG as method of teaching.	3
Paiva et al.[38]	Brazil	Prototype description	Biosecurity in dentistry	University	No	Undergraduate dental students	Computer (Quiz, rewards, levels)	The player's objective is to show his knowledge in correctly answering all the challenges that are presented and to collect Personal Protective Equipment items in the scenario, increasing or decreasing, therefore, the level of biosafety that will define the player's success or not. Thus, as the challenges are answered correctly, the level of biosafety will be increased and as the player misses the same level it will be decreased, with the proliferation of viruses intensified.	N/A	1
de Vasconcelos et al.[39]	Brazil	Qualitative	Dental prothesis	University	No	Undergraduate dental students	Mobile (Quiz, levels)	The player is a candidate for a vacancy of prosthesis team of a famous dental clinic. To be hired, the candidate will go through three stages, initial interview, internship, and residency. At each stage, the user faces increasing levels of difficulty, being supervised by his supervisors with questions composed of a scenario, a question, and answer options.	Usability test showed full acceptance on the part of students and teachers. Besides the teachers perceive an improvement of the overall performance of the class.	2
Vahed[40]	South Africa	Qualitative	Teeth morphology	University	Yes Framework for the Rational Analysis of Technology Education	Undergraduate dental students	Computer web-based (Quiz, levels)	Web-based game consisting of five sub-games that correspond to different levels about questions related to discipline content of tooth morphology and oral anatomy.	The students declared high level of satisfaction using the SG. They also made some suggestion to improve the game.	2

(*continued*)

Table 4. (Continued)

References	*Country*	*Study design*	*Topics*	*Setting*	*Theoretical model specified*	*Target group*	*Device (game elements)*	*Description of the SG*	*Main results*	*Quality study assessment*
Ribeiro et al.[41]	Brazil	Qualitative	Anaesthesia	University	No	Undergraduate dental students	Haptic device (Training simulation quiz, rewards, levels, points)	The player must apply anesthesia in the correct place, using adequate angulation and with an ideal injection depth. According to the form of the execution of the anesthetic action, a score is awarded. To encourage players to get better scores, a ranking system is in place.	Evaluation by experts of the prototype of the SG showed that the gamification process was successful.	2
Rodríguez-Andrés et al.[42]	Spain	Quasi-experimental	Teeth morphology	University	Yes Behavioural learning theory	Undergraduate dental students	Microsoft Kinect© (Autostereoscopy)	The main goal of the user is to place each tooth in its correct position. Looking closely at the 3D models from all angles, the students can observe minimal details that help them to identify each tooth in order to place it in the right position. The game is divided into two principal stages (1. Learning stage and 2. Placement stage).	Students demonstrate a statistically significant for the acquired knowledge. However, there was not difference between the two modes: neutral and real-world.	5
Sipiyaruk et al.[43]	United Kingdomx	Quasi-experimental	Dental public health.	University	Yes Games learning theory	Undergraduate dental students	Computer Moodle environment (Quiz, feedback)	The users are exposed to the learning scenario on a virtual town. A variety of health promotion interventions were provided as possible options that the student must choose.	The pilot program showed a positive feedback by the students, but the scoring system and more interaction with the user is needed.	2.5
Feitosa et al.[56]	Brazil	Qualitative	Biosecurity in Dentistry	University	No	Undergraduate dental students and dentist	Computer and mobile (Quiz, rewards, levels, points, audio, ranking)	The educational game uses a 2D interface and provides a learning environment on biosafety based on an educational quiz game. The response time for each question depends on the level of difficulty and is presented gradually.	The technical evaluation by experts showed that the SG had a good textual clarity criterion, presented practical relevance, was adequate to the public, and had good response time of the questions.	2
Oral health promotion										
Chang et al.[45]	Taiwan	Quasi-experimental	Oral Hygiene	School	Yes Teaching-learning theory	Children from 72 to 81 months	Computer (Avatar)	Tooth brushing game in which the child cleans a virtual, mirror picture of his/her dirty teeth by physically brushing his/her own teeth	Playful Toothbrush improves the tooth brushing skills of children within a relatively short training period. After using the Playful Toothbrush for five consecutive days, children exhibited significant improvement in effectiveness of teeth cleaning, increased number of brushing strokes, longer brushing time, and more thorough brushing coverage in teeth areas	3,5

(*continued*)

Table 4. (Continued)

References	*Country*	*Study design*	*Topics*	*Setting*	*Theoretical model specified*	*Target group*	*Device (game elements)*	*Description of the SG*	*Main results*	*Quality study assessment*
Gerling et al.[46]	Germany	Qualitative	Diet, oral hygiene	School	Yes Bloom's taxonomy of learning theory	Children from 9 to 11 years	Console game (Feedback, levels, points)	The game has two game modes, nutrition-mode and cleaning-mode. In nutrition-mode, the player has to take care of a group of teeth advancing through the game in a style similar to 2D side-scrolling games After switching to the cleaning-mode, the player is asked to choose from a set of three cleaning instruments. Depending on the player's choice, an adequate input device allowing the conduction of different cleaning gestures has to be selected through WIImote.	Focus group showed that new technologies offer great opportunities for educational games, because they have the potential to engage children in a playful learning process. The teacher highlighted that the SG could be used in a classroom context to introduce the topic of dental hygiene.	4
de Morais et al.[47]	Brazil	Qualitative	Oral health of the infant	Health Service	Yes Games learning theory	Parents	Computer (Avatar)	In this game, the avatar should care for a princess whose birth was cursed by the wizard Tartarus; if the princess has any dental problems, everyone in the kingdom will have sad smiles and rotten teeth. So that this does not happen, the player is motivated to help the king and queen to prevent this curse from materializing.	In general, the mothers considered of interest the idea of SG addressing this issue. About 90% of mothers reported that it is very easy to understand the messages and discourses using an SG.	1.5
Dotta et al.[48]	Brazil	Qualitative	Oral health of the infant	School	No	Children from 5 to 7 years	Computer Flash for web (Avatar, quiz)	The central character of Dr. Treats Tooth, who is a superhero, represented by the figure of a child dentist, and the background image of the game is the clinical room of this small dentist and it has three sub-groups: Game of Association between Drawings, Memory Game, and Painting Game.	Expert analysis showed that the game allows to achieve the objectives proposed, which include teaching oral health	3
Ito et al.[49]	Brazil	Qualitative	Preschool oral health	Preschool	No	Preschool children from 3 to 5 years	NR (Avatar)	The player through avatar should keep the tooth sound. Players evaluate the advantages of decision making, with options that may not be entirely positive or negative.	Evaluations by parents, teachers, and dentists recognize that it is important to have a digital game of dental prevention for children. Overall, 97.39% of the interviewed found that the prototype of the game presented as stimulating and attractive to the target audience.	2.5

(*continued*)

Table 4. (Continued)

References	*Country*	*Study design*	*Topics*	*Setting*	*Theoretical model specified*	*Target group*	*Device (game elements)*	*Description of the SG*	*Main results*	*Quality study assessment*
Figueiredo et al.[50]	Brazil	Quasi-experimental	Dental caries, diet, oral hygiene	School	Yes Games learning theory	Children from 6 to 14 years	Mobile (Avatar, autostereoscopy, levels, points)	The game is based on the adventure of the main character, a molar tooth, which acts against bacteria and against sugars found in food, with the help of a brush, cream, dental floss, and healthy foods, in an environment that represents the oral cavity. It presents several phases, in which hygiene and healthy eating are the resources to overcome them, and at the end of the game, oral health is achieved.	The SG showed a good acceptation by the end users. Children reported that by playing SG they learned that brushing their teeth is good for their health.	1.5
Aljafari et al.[51]	United ingdom	RCT	Diet, oral hygiene	Hospital	Yes Social cognitive theory	Children 4–10 years old referred for extraction of decayed teeth under general anesthesia	Computer Mobile (Avatar)	The game through avatar (Hamster) provides advice about oral health. No more information.	The SG group reported improvement in recognition of unhealthy foods. They also reported improvements in diet, including reducing sweetened drinks and non-core foods intake. No significant differences in dietary habits or oral hygiene between SG group and conventional promotion were found.	3.5
Campos et al.[12]	Brazil	Quasi-experimental	Dental caries, diet, oral hygiene, dentitions and oral habits	Preschool	Yes Not clearly specified	Preschool children from 3 to 5 years of age	Mobile (Avatar)	The game through avatar provides advice about oral health. The player is challenged to perform different activities, such as putting healthy food into the mouth.	The SG was effective to consider the following usability attributes: effectiveness (the potential of the interface to be understood by the user); efficiency (by way of easy navigation); and satisfaction (that is user friendly)	4.5
Huntington et al.[52]	United Kingdom	RCT	Information for families underwent dental treatment under general anaesthesia.	Hospital	No	Children aged 5–7 with Early Childhood Caries that need general anesthesia	Online computer (Avatar)	Through an avatar named Scott, the family gets to know the hospital and is given advice on dental care.	There were no statistically significant differences in controlling children's anxiety between groups. However, families believed that a videogame preparation helped their child's perioperative anxiety.	4
Jacobson et al.[53]	USA	Quasi-experimental	Oral Hygiene	Home	Yes Not clearly specified	Children from 5 to 6 years	Computer (Training simulation)	Brush Up™ teaches the child to brush along with a song that lasts three minutes. The tempo sets the pace of sulcus strokes and sweeps. The rhythm counts off 12 miniscule strokes and three broad sweeps for each tooth surface before advancing to the next. The song and accompanying video progress through the mouth sequentially from tooth to tooth.	There were significant improvements in the quality of toothbrushing, in both the toothbrushing time and tooth brushing distribution.	3.5

2D, two-dimensional; 3D, three-dimensional; RCT, randomised clinical trial; SG, serious game.

conference proceedings. The majority of studies ($n=12$) were published in journals and seven as conference proceedings. The journals were either not ranked or belonged to the Q3 or Q4 of the JCR ranking. Three studies[51,52] were published in a Q2 journals. For those published in conference proceedings, only two were ranked according to the CORE ranking.[37,42]

RQ6: What is the theory behind the design of SGs in dentistry?

Ten studies did not report any theory-based conceptual model. These studies were either expert or users' technical evaluations of prototypes,[38,39,41,44,48,49] or due to unclear reports of the use to the theoretical framework utilized to develop the game, it was not possible to determine.[6,12,52,53] Of these, three studies did not state the theoretical model used to develop the game,[6,12,52] and another indicated that the game was theory based, but a theoretical background was not reported.[53]

Of the remaining SGs, in four the evidence indicated that some Game-Based Learning Theory was employed,[37,43,47,50] and another five used different theories to conceptualize the process of game-based learning, including the social cognitive theory[51]; the Framework for the Rational Analysis of Technology Education model[40]; teaching learning theory[45]; Bloom's learning domain model[46]; and behavioral learning theory.[42]

RQ7: What is the effectiveness of SGs in dentistry?

Excluding studies with no evaluations ($n=2$), three studies were as effective as traditional, noninteractive methods in improving outcomes[6,43,52]; another three did not use comparisons groups.[12,42,50] One study reported better outcomes than traditional education/interventions.[51] Two studies showed that the game improves the toothbrushing skills.[45,53] Aljafari et al.[51] reported improvement in the recognition of unhealthy foods, improvements in diet, including reducing sweetened drinks and noncore foods intake. The other eight studies either reported qualitative evaluations by small samples of end users,[40,46,47,49] or were technical evaluations by experts[41,44] and their effectiveness was difficult to assess. Overall, however, the results from the studies would indicate a higher level of satisfaction in learning through games.

Discussion

The aim of our scoping review was to establish how SGs have been developed and used in oral health. After the selection process, 19 studies met our inclusion criteria, covering a range of oral health-focused games. Those studies showed a substantial variability in study design, target population, characteristics of the game, outcome measures, and results. Some of the studies reviewed involved oral health profession students' learning clinical skills, clinical problem solving, patient management, and/or other professional and basic sciences knowledge. In addition, SGs were found to be used in oral health promotion and education for specific populations (e.g., preschool and school children).

RQ1: How is the research focused on SG in dentistry distributed?

The evidence of SG in Dentistry is very recent. Our findings suggest that there is a gap in the literature and in the mobile game market regarding the use of SGs in oral health, compared with other health fields. For example, a single PubMed search on games in medicine produced 797 hits. Despite this, current findings showed a general increase in publications of studies after 2013.

Caution should be exercised when generalizing the findings, because most of the studies came from Brazil. However, there is a growing interest in the field throughout the world. The only continent that was not represented was Oceania.

RQ2: What are the design types of the studies related to SGs in dentistry?

Since most of studies identified were prototype descriptions and qualitative studies, it was not possible to assess the effectiveness of SGs for the purpose for which they were developed. Only three RCTs were identified, therefore, further research using RCT are needed to provide stronger evidence of the effectiveness of SGs and to uncover the benefits and limitations of their use in the oral health field. This is consistent with that reported by Sipiyaruk et al. in their review on SGs in dental education, where they only identified one RCT.[60] However, in other health, RCT was more frequently used to assess the effectiveness of the SGs.[1]

RQ3: What are the purposes and topics for which SGs in dentistry are developed?

We identified two main categories: dental educational and oral health promotion. Although the SG topics developed for educational purposes were varied, a few were created for postgraduate students or professionals. Although the evidence is not conclusive, evidence shows that SGs can improve the skills or knowledge of health care professionals.[61]

In relation to oral health promotion, all SGs, except one, were developed for children. Despite the lack of evidence found in the adult population in the oral health field, evidence in other health areas has shown that SGs are effective even in the elderly population.[62] Therefore, more studies that include the adult population are necessary in the field of health promotion of oral health.

RQ4: What are the platform and elements used in SGs in dentistry?

A poor description of the game elements in most of the articles identified was reported; therefore, this makes it difficult to attribute some effects to individual game elements.

For dental education games a quiz was the main element used. Those are games designed to test the knowledge of the players by rewarding players who can successfully answer a question[60] Evidence supports that rewards drive health behaviors.[63] Feedback was also frequently integrated in the SGs; however, the type of feedback (sound, text, or visual) was not stated in most of the studies. It has been pointed out that the adjustment of real-time feedback is crucial, because the game needs to provide feedback appropriate to the level of the user.[15]

Avatars are commonly employed as a gamification technique to represent the user in the application context.[63] The evidence shows that avatars are associated with positive outcomes, mainly because they were found to increase motivation.[64] Although SG included in our review show an improvement in health outcomes, it was not better than for the control groups.

Unlike what was reported in other reviews on SGs, none of the SGs included implemented a socialization component as a motivational strategy.

RQ5: What is the methodological quality of the reports about SGs in dentistry?

None of the included studies met all of the factors included in the quality assessment checklist. The quality of the studies was limited due to small samples, limited age range of participants, lack of a comparison group, length of follow-up periods to review knowledge retention, and poor follow-up attendance. In addition, none of the games included were tested in different settings or in a population with different cultural backgrounds, so their effectiveness can hardly be evaluated. In addition, most of the reports of SGs were published in journals with limited impact and visibility, making it difficult to disseminate and implement them in other settings. These findings are consistent with other systematic reviews of SGs in other health fields, which show that the effectiveness of SGs over traditional approaches is inconclusive.[1,60]

RQ6: What is the theory behind the design of the SGs in dentistry?

This review indicated that there may still be room to improve in several areas, for example, in the use of theory in the design of SG. SGs content and design must be driven by sound learning and behavioral change theories. Several key theories underpin the design of SGs.[5,65,66] Nonetheless, in the present review, only about half of the studies declared the pedagogical or theoretical perspective used to develop the SGs.[6,12,37,40,42,43,45–47,50,51,53] At a minimum level, they all would fit Ericsson et al.'s theory of deliberate practice.[5] Thus, it is implied that the SGs were not based on sound theories, merely that those theories were not clearly presented. The use of theory in the design of SGs is an important aspect to consider since their perspective determines the intentions of the game's authors and the architecture of the games. However, the evidence shows that the connection between pedagogical perspectives and SGs is weak, since the developers are more concerned with the practical aspects of their games than their theoretical fundaments.[7,66]

Gorbanev et al. explored pedagogical strategies used by developers when creating games for medical education, concluding that developers who used pedagogical strategy designed more robust games, which facilitated the learning process. They also concluded that behaviorism and cognitivism were the main pedagogical strategies incorporated by the developers.[7] For these purposes, it is important that the games be developed together with designers, educators, and public health practitioners to resolve appropriately a specific educational or oral health problem. This would also allow for a better theorization of the evaluation design of the SG.[67]

RQ7: What is the effectiveness of SGs in dentistry?

This review found limited empirical evidence available to confirm games' effectiveness. Some studies only reported a description of the game or were in their pilot phases; consequently, the evidence available from these projects is only partial to allow for their complete assessment. In the present review, six quasi-experimental designs and three randomized clinical trials were identified. Studies that provided some effectiveness evaluation were found to be as effective as conventional, noninteractive methods in improving outcomes (i.e., teaching oral health concepts).

The SGs must be reviewed and scrutinized, and proof of their validity, efficacy, and effectiveness must be presented. Several aspects of SGs should be evaluated before their implementation, such as game design, user's satisfaction, usability, usefulness, understandability, motivation, performance, playability, pedagogical aspects, learning outcomes, engagement, user's experience, efficacy, social impact, enjoyment, acceptance, and user interface, as well as privacy, security, and safety.[68] Only then can SGs be considered as learning aids or health promotion tools. However, the included reports only considered some of these aspects, which were mostly poorly described. Games that are well designed and that integrate the game's technology adequately have higher levels of usability and acceptability by end users; thus, they are more successful in engaging users in game content and in achieving better outcomes.[69]

Implications of the results

One of the advantages of SGs over conventional learning strategies is that they can be developed and adapted according to the characteristics of the target populations (e.g., age, learning styles, cultural background, etc.).[70] In this respect, findings would indicate that because of differing learning styles, more studies involving diverse populations are recommended to identify effective gamification strategies. This study shows how SG technologies can be related to learning and education and have the potential to improve knowledge, attitudes, and behaviors in relation to oral health in the general population. However, as with teaching, there are limited data on their effectiveness and outcome. Still, although gamification has been successful, thorough research on the validity of SG and their effectiveness are required before wide implementation.

From a public health perspective, additional information and evidence of the usefulness of SGs in oral health will not only increase present knowledge regarding the use of gamification, but this information will also provide the necessary evidence to support maintenance, future expansion, or the introduction of this technology, under specific conditions prevailing in particular situations and populations. Although there may be many logistic or practical situations that might render gamification unsuitable for all populations, our contention is that expansion of their use in oral health will increase in the future. Although current results provide limited evidence, they tend to suggest that gamification has the potential to be successful. The review also highlights the limitations of how studies are reported. To provide more attractive and robust input to decision makers, further studies are required for using more rigorous designs, evaluation, and follow-ups.

Limitations during review process

Although we were systematic in our review, it is possible that we may have missed publications. However, we believe that this was minimized due to the sensitive search strategy

used, the additional search of references by hand, and the double independent review process used. In addition, the gray literature was not systematically reviewed; therefore, some conference papers or ongoing RCT may not have been identified.

Quality assessment was hampered by poor reporting of included studies. We tried to contact the authors for more information but did not get a satisfactory answer.

Conclusions

Despite the strengths of this scoping review, it is worth noting that we did not distinguish by type of design and included articles that described the prototype or that made a qualitative evaluation of the games. Nor did we limit by time period. The overall methodological quality of the studies included was poor, so the findings assessed in the included studies should be interpreted with caution. In summary, SGs are used scarcely in oral health, and there is little valid empirical evidence available to confirm their effectiveness.

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