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Playful Prevention Reconsidered: A Critical Narrative Review of How Game Design Constrains Clinical Content and Behavioural Durability in Paediatric Oral Health Gamification

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Abstract

Background: Three recent syntheses have established that gamified oral health education outperforms conventional instruction on short-term measures of knowledge, plaque and gingival health. Attention should therefore shift from whether these tools work to why their clinical coverage is narrow and their effects poorly sustained.

Objectives: To advance and test two propositions: first, that the clinical content of gamified paediatric oral health tools is selected by what game mechanics can conveniently express rather than by preventive importance (a design and content inversion); and second, that the behaviour change techniques embedded are almost exclusively behaviour-initiating rather than behaviour-maintaining, making engagement decay a designed-in property rather than an implementation failure.

Methods: A critical narrative review was conducted in accordance with the Scale for the Assessment of Narrative Review Articles. Six databases were searched from January 2014 to January 2026, combining the concepts of gamification, paediatric population and oral health. Interventions were coded against a 31-element taxonomy of game design elements and against the Abraham and Michie taxonomy of behaviour change techniques, and the resulting distributions were interrogated against the requirements of evidence-based preventive dentistry.

Results: Short-term effectiveness is consistent, with plaque score reductions of up to 63.4 per cent, gingival score reductions of up to 58.7 per cent, and regular engagement of 72.4 per cent against 48.3 per cent for non-gamified equivalents. Content distribution, however, tracks gamifiability rather than clinical importance. Brushing time, which maps directly onto a countdown timer and is therefore expressed by the most prevalent game element (present in 94 per cent of applications), is near-universal, whereas interdental cleaning appears in under 20 per cent of applications, correct dentifrice quantity in two of seventeen, and toothbrush grip and tongue cleaning in none. The distribution of behaviour change techniques shows a parallel asymmetry, with initiating techniques dominant (31 to 42 per cent) and maintaining techniques minimally represented or absent.

Conclusions: Gamified paediatric oral health tools are engaging but clinically incomplete, and their engagement decay is predictable from the behaviour change content they contain. Both failures share one cause, namely that mechanics are determining content rather than content determining mechanics. Reversing this inversion, rather than accumulating further short-term efficacy trials, is the substantive task for the field.

Keywords: Gamification, Paediatric Dentistry, Oral Health Education, Behaviour Change Techniques, Mobile Health, Evidence-based Dentistry, Serious Games, Intervention Design

1. Introduction

1.1 A behavioural disease and a behavioural bottleneck

Oral health is inseparable from general health and exerts a measurable influence on a child's growth, nutrition, speech development, sleep, school performance and self-esteem [1, 2]. Untreated dental caries in the primary dentition remains among the most prevalent conditions affecting humankind, and the global burden of oral disease has not declined in age-standardised terms over three decades [2, 3]. Its consequences extend beyond the dentition to impaired oral health-related quality of life for the child and family, disturbed sleep, reduced weight gain, school absenteeism and diminished academic performance [4, 5, 6].

What makes this burden distinctive is that its proximal determinants — plaque removal, fluoride exposure and the frequency of fermentable carbohydrate intake — are behavioural before they are biological. The bottleneck in paediatric caries prevention is therefore not a deficit of efficacious agents but a deficit of durable behaviour, and it is this bottleneck that oral health education has long been charged with relieving [7].

1.2 The failure of conventional oral health education

The evidence base for conventional oral health education is considerably weaker than its ubiquity would suggest. Systematic appraisals have repeatedly concluded that didactic health talks, pamphlets and one-off chairside instruction generate short-lived knowledge gains that translate inconsistently into behavioural or clinical change, and that any gains attenuate rapidly once reinforcement ceases [8, 9, 10]. The reasons are structural: didactic instruction is unidirectional and provides no feedback loop; it targets knowledge, a weak predictor of behaviour, rather than motivation, self-efficacy or habit; it is delivered episodically rather than at the moment of behaviour; and its idiom is mismatched to the attentional characteristics of the paediatric learner, whose expectations have been shaped by interactive, responsive and reward-rich media.

1.3 Gamification and the evidence that it works

Gamification is defined, following Deterding and colleagues, as the use of game design elements in non-game contexts [11]; a complementary service-marketing definition frames it as enhancing a service with affordances for gameful experiences in support of the user's value creation [12]. It should be distinguished from adjacent constructs with which it is frequently conflated.

A serious game is a complete, self-contained game whose primary purpose is other than entertainment; game-based learning denotes the use of a game as the instructional vehicle; and gamification proper refers to the insertion of discrete game elements — points, levels, badges, avatars, progress bars, challenges, leaderboards, narrative — into an activity that is not itself a game, such as toothbrushing. The distinction is not pedantic: it determines whether an observed effect can be attributed to a specific mechanism or only to a bundle.

Its theoretical justification is well established, resting principally on Self-Determination Theory, which holds that behaviour is durably internalised only when autonomy, competence and relatedness are supported [16], and on the COM-B model and Behaviour Change Wheel, which specify capability, opportunity and motivation as the necessary conditions for behaviour [35]. Empirically, gamified interventions have demonstrated benefit across physical activity, medication adherence, chronic disease self-management and mental health, with effects strongest where the target is behavioural rather than cognitive [13, 14, 15, 37, 38].

Within paediatric oral health specifically, the question of whether gamification works may now reasonably be regarded as settled in the affirmative for short-term outcomes. Moreira and colleagues mapped the mechanisms and behaviour change techniques of fifteen studies in a scoping review [18]; Patil and colleagues confirmed the superiority of game-based over conventional teaching across randomised trials [20]; and Chen and colleagues synthesised 41 studies, finding digital gamified interventions consistently superior to non-digital alternatives and reporting regular engagement of 72.4% against 48.3% for non-gamified comparators [17]. Individual trials report effects of considerable magnitude, most notably a 63.4% reduction in plaque score and a 58.7% reduction in gingival score at three months following an interactive game-based visual performance intervention in Indian adolescents [22].

1.4 The question that has not been asked

Because the effectiveness question has been answered three times over, continuing to ask it yields diminishing returns. Two observations, each reported in the existing literature but neither pursued to its implication, suggest a more productive line of inquiry.

The first concerns content. Fijačko and colleagues, screening 612 applications from six stores, found that only 17 met minimal criteria for gamification features combined with evidence-based content, and that those seventeen contained on average approximately three of ten evidence-based dentistry content items [19]. Moreira and colleagues, examining a partially overlapping set, found brushing time defined in 100% of the evidence-based applications and daily brushing frequency in 91%, but toothbrush grip and tongue cleaning mentioned in none at all [18]. These figures are usually reported as evidence of poor quality control. They are more interesting than that.

The second concerns durability. Both Moreira and colleagues and Chang and colleagues note that children’s interest declines once novelty is exhausted [18, 24], and Chen and colleagues found that 24% of studies included no long-term follow-up whatever, with follow-up rarely exceeding three months in those that did [17]. This too is conventionally reported as a limitation of the evidence. It may instead be a property of the interventions.

1.5 Two propositions

This review advances two related propositions which, taken together, offer a structural rather than incidental explanation for both observations.

Proposition 1 — the design–content inversion. The clinical content present in gamified paediatric oral health tools correlates not with its preventive importance but with its gamifiability. Brushing time maps directly and trivially onto a countdown timer, and time pressure is the single most prevalent game element in this field, present in 94% of applications [19]; brushing time is correspondingly the near-universal content item. Toothbrush grip, interdental cleaning sequence, the pea-sized dentifrice quantity, spitting without rinsing and tongue cleaning have no natural expression as game mechanics, and are correspondingly absent. The design vocabulary is silently selecting the clinical curriculum — an exact inversion of the order in which a clinically governed intervention would be constructed.

Proposition 2 — the initiation–maintenance asymmetry. Coding these interventions against the Abraham and Michie taxonomy reveals that the behaviour change techniques actually embedded are overwhelmingly those that establish a behaviour — prompting intention formation and providing instruction (42% each), modelling the behaviour and providing information on consequences (35% each), providing feedback and contingent rewards (31% each) — while those that maintain a behaviour, namely barrier identification, relapse prevention, planning social support and goal review, are minimally represented or absent [18]. Engagement decay is therefore not a failure of implementation to be remedied by better content updates; it is the predicted consequence of the behaviour change content that has been built in.

The two propositions share a root cause. In both cases, what the tool does is being determined by what the medium finds easy, rather than the medium being engineered to deliver what the clinical problem requires. Recognising this reframes the field's central task: not to accumulate further demonstrations of short-term plaque reduction, but to reverse the inversion.

1.6 What this review adds, and its objectives

This review is deliberately not a fourth synthesis of effectiveness; readers seeking formal effect appraisal are directed to the existing systematic and scoping reviews [17, 18, 20]. Its contribution is interpretive. Where those reviews catalogue what gamified interventions contain and what they achieve, this review asks why they contain what they contain, and argues that the answer explains their characteristic pattern of success and failure. To the authors' knowledge, neither the design–content inversion nor the initiation–maintenance asymmetry has previously been stated as an explanatory claim, and no prior review has connected the two.

The specific objectives were as follows:

1. To situate gamification within the behavioural science that justifies its use, and to specify the taxonomies of game design elements and behaviour change techniques against which interventions can be audited.
2. To map the modalities through which gamification reaches children — mobile applications, sensor-linked toothbrushes, serious games, augmented reality, conversational agents and non-digital formats — and to appraise the outcomes achieved by each.
3. To test the design–content inversion by relating the observed prevalence of clinical content items to their gamifiability rather than to their preventive importance.
4. To test the initiation–maintenance asymmetry by relating the distribution of embedded behaviour change techniques to the observed pattern of engagement decay.
5. To derive from these analyses a set of concrete corrections for design, clinical integration and future research, including the corrections required before gamification can reasonably be recommended as a component of the preventive care pathway.

2. Materials and Methods

2.1 Review design

This work is presented as a structured narrative review. The choice of design was deliberate. The question addressed — how gamification has been conceptualised, delivered, and evaluated across heterogeneous populations, platforms and outcome domains — is one of breadth and mechanism rather than of a single quantifiable effect estimate, and the constituent literature spans randomised trials, application-store evaluations, usability studies, development papers and prior reviews that cannot meaningfully be pooled. To mitigate the recognised susceptibility of narrative reviews to selection bias, the review was conducted against the six-item Scale for the Assessment of Narrative Review Articles (SANRA) [26], and the search, eligibility and extraction procedures are reported transparently below in accordance with published guidance on narrative review methodology [27]; reporting of the search and selection process was additionally informed by the PRISMA 2020 statement where its items were applicable to a non-systematic design [28]. This review does not claim the exhaustiveness of a systematic review, and readers are directed to the recent systematic and scoping syntheses for formal effect appraisal [17, 18, 20].

2.2 Information sources and search strategy

Six sources were interrogated: PubMed/MEDLINE, Scopus, Web of Science, the Cochrane Central Register of Controlled Trials, Embase and Google Scholar (first 200 records, sorted by relevance). The search covered publications from 1 January 2014 to 31 January 2026, the lower bound being chosen because gamification entered the oral health literature only after approximately 2013. Reference lists of all included reviews and trials were hand-searched, and forward citation tracking was performed on the four key reviews [17, 18, 19, 20].

The search combined three concept blocks using Boolean operators. The PubMed strategy, adapted for the syntax of each database, was:

("gamification"[MeSH] OR gamif*[tiab] OR "serious game*"[tiab] OR "game-based"[tiab] OR "video game*"[tiab] OR "board game*"[tiab] OR "mobile application*"[tiab] OR "mHealth"[tiab] OR "smartphone app*"[tiab] OR "augmented reality"[tiab] OR chatbot*[tiab]) AND (child*[tiab] OR p?ediatric[tiab] OR adolescen*[tiab] OR schoolchild*[tiab] OR preschool*[tiab]) AND ("oral health"[MeSH] OR "oral hygiene"[tiab] OR "dental caries"[tiab] OR toothbrush*[tiab] OR plaque[tiab] OR gingivitis[tiab] OR "dental health education"[tiab])

2.3 Eligibility criteria

Records were eligible if they concerned children or adolescents aged 3–18 years; evaluated, described or synthesised an intervention incorporating one or more identifiable game design elements directed at an oral health outcome; and reported at least one measurable clinical, cognitive, behavioural, psychosocial or engagement outcome. Eligible designs comprised randomised and non-randomised controlled trials, quasi-experimental and pre–post studies, prospective cohorts, cross-sectional application evaluations, usability studies and previously published systematic, scoping or narrative reviews. Only English-language, peer-reviewed, full-text publications were included.

Records were excluded if the population was exclusively adult; if the intervention contained no game element (for example, a purely informational video or leaflet); if the outcome lay outside the oral health domain; or if the record was an editorial, commentary, conference abstract without accessible data, or a protocol without reported results. Studies of audiovisual distraction during operative dentistry were included only where a game element was integral to the intervention rather than incidental.

2.4 Data extraction and synthesis

Data were extracted into a structured matrix capturing bibliographic details, study design, setting, sample size and age range, intervention modality and platform, comparator, the specific game design elements present (coded against the 31-element taxonomy applied by Fijačko and colleagues [19] and derived from Blohm and Leimeister [29]), the behaviour change techniques present (coded against the Abraham and

Michie taxonomy [30] and the CALO-RE refinement [31]), the underpinning behavioural theory where stated, outcome measures, follow-up duration and principal findings.
Synthesis was thematic. Studies were first grouped by delivery modality and subsequently re-examined by outcome domain, permitting the same trial to inform more than one section. Where quantitative results are reported, the figures are those stated by the original authors; effect estimates have not been recalculated or pooled. Because of the diversity of designs, outcome instruments and follow-up intervals, a meta-analysis was neither attempted nor considered appropriate — a judgement shared by all four preceding reviews in this field [17, 18, 19, 20].

3. Conceptual Foundations: Why Gamification Should Work

3.1 The anatomy of a gamified intervention

A gamified oral health intervention can be decomposed into a set of discrete, individually specifiable elements. The taxonomy most widely applied in this field, comprising 31 elements grouped into five superordinate categories, was operationalised by Fijačko and colleagues in their appraisal of commercially available applications and has since been reused in the scoping literature [19, 29]. Its value is that it converts the vague claim that an intervention is "gamified" into an auditable specification (Table 1).
Applying this taxonomy to seventeen evidence-screened oral hygiene applications, Fijačko et al. found a mean of only 6.87 of 31 possible elements per application, with time pressure present in 94%, virtual characters in 82% and fantasy in 76%; conforming behaviour and leaderboards were each present in only 3% [19]. Moreira and colleagues, examining a partially overlapping set of studies, reported a mean of 10.6 elements and identified ideological incentives (83%), goals (56%), ownership (41%) and meaning (28%) as dominant, with badges, self-expression, virtual goods and conforming behaviour entirely absent [18]. The convergent finding is important: contemporary paediatric oral health applications draw on a narrow and somewhat impoverished subset of the available design vocabulary, concentrating on timing and character-driven engagement while neglecting social, identity and progression mechanics that are heavily exploited in the commercial games these children actually play.

Table 1: Taxonomy of Game Design Elements Applied to Paediatric Oral Health Interventions

Category	Constituent elements	Representative expression in paediatric oral health
System design	Visual feedback; audible feedback; reminder; meaning; interaction concepts; visual resemblance to existing games; fantasy	A cartoon avatar whose teeth visibly brighten as brushing proceeds; a song of exactly two minutes; a push notification at 21:00; a narrative in which plaque monsters must be defeated
Challenges	Goals; time pressure; progressive disclosure	A two-minute countdown timer; quadrant-by-quadrant unlocking; a weekly target of fourteen brushing episodes
Rewards	Ownership; achievement; point system; badges; bonus	Coins earned for completed sessions; a virtual pet that must be cared for; accessories unlocked by consecutive days of adherence

Category	Constituent elements	Representative expression in paediatric oral health
Social influences	Loss aversion; status; collaboration; reputation; competition; envy; shadowing; social facilitation; conforming behaviour; leaderboards; altruism; virtual goods	Classroom leaderboards in Kahoot-style quiz sessions; sibling or peer comparison; a streak that is lost if brushing is missed
User specifics	User levels; ideological incentives; virtual characters; self-expression	Selectable avatars; customisable backgrounds and music; graduated levels of brushing "expertise"

Taxonomy after Blohm and Leimeister and as operationalised by Fijačko et al. [19, 29].

3.2 Theoretical frameworks underpinning gamified oral health interventions

3.2.1 Self-Determination Theory

Self-Determination Theory distinguishes intrinsic motivation, which arises from the inherent satisfaction of an activity, from extrinsic motivation, which depends on separable consequences, and proposes that behaviour is durably internalised only when autonomy, competence and relatedness are supported [16]. Gamification maps onto this framework with unusual directness: choice of avatar, difficulty level and reward pathway supports autonomy; graded challenge with immediate feedback builds competence; and collaborative or comparative features support relatedness. This mapping also predicts the principal failure mode of poorly designed gamification, namely that reward-heavy, choice-poor systems induce a purely extrinsic dependency which collapses when the reward is withdrawn — a phenomenon consistent with the decay of engagement observed once novelty passes [18, 34].

3.2.2 The COM-B model and the Behaviour Change Wheel

The COM-B model proposes that behaviour (B) arises from the interaction of capability (C), opportunity (O) and motivation (M), and the Behaviour Change Wheel provides a systematic route from this diagnosis to intervention functions and specific behaviour change techniques [35]. Its explicit use in paediatric oral health is exemplified by Chang and colleagues, who designed a gamified conversational agent for Taiwanese children by first diagnosing the behavioural deficit in COM-B terms and then selecting intervention functions accordingly, achieving a usability score of 79.91 out of 100 [24]. The systematic review by Chen et al. found that theory-driven interventions of this kind were consistently associated with better engagement and effect than atheoretical designs [17].

3.2.3 Social Cognitive Theory and the Theory of Planned Behaviour

Social Cognitive Theory contributes the constructs of observational learning, self-efficacy and reciprocal determinism, and is the explicit basis for the modelling and demonstration functions embedded in avatar-guided brushing applications [32]. The Theory of Planned Behaviour contributes attitudes, subjective norms and perceived behavioural control, and has been used to structure parent-facing components in which the caregiver's normative beliefs are the proximal target [17, 33]. Chen and colleagues found social cognitive theory, behavioural reinforcement and the Behaviour Change Wheel to be the most frequently declared frameworks among experimental studies, although a majority of studies still declared no theoretical basis at all [17].

3.3 Behaviour change techniques as the active ingredients

If game elements are the delivery vehicle, behaviour change techniques are the active pharmacological ingredient. Coding gamified oral health interventions against the Abraham and Michie taxonomy of 26 techniques, Moreira and colleagues identified a consistent core of seven that account for the majority of embedded content: prompting intention formation and providing instruction (each 42%), providing information on the behaviour–health link (38%), providing information on consequences and modelling or demonstrating the behaviour (each 35%), and providing feedback on performance and providing contingent rewards (each 31%) [18]. Techniques concerned with relapse prevention, barrier identification, social support and stress management were markedly under-represented (Table 2).

This distribution is the evidential basis of Proposition 2. The techniques that are well represented are those that establish a behaviour; the techniques that are under-represented are precisely those that maintain a behaviour once established. The observed pattern of strong short-term effects followed by engagement decay is therefore not an accident of implementation, to be remedied by more frequent content updates, but a predictable consequence of the behaviour change content that has actually been built into these tools. A tool constructed almost entirely from initiating techniques should be expected to initiate and then to stop working, which is what the follow-up data show.

Table 2: Behaviour Change Techniques Embedded in Gamified Paediatric Oral Health Interventions

Behaviour change technique	Frequency	Function and design correlate
Prompt intention formation	High (42%)	Goal-setting screens; commitment to a daily brushing target
Provide instruction on how to perform the behaviour	High (42%)	Step-by-step brushing tutorials; quadrant sequencing
Provide information on behaviour–health link	High (38%)	Narrative explanation of plaque, caries and gingival bleeding
Provide information on consequences	Moderate (35%)	Visual depiction of cavitation or gingival inflammation
Model or demonstrate the behaviour	Moderate (35%)	Avatar or video modelling of the modified Bass technique
Provide feedback on performance	Moderate (31%)	Sensor-derived coverage maps; session scoring
Provide contingent rewards	Moderate (31%)	Coins, badges, unlockable accessories
Prompt self-monitoring; review of goals	Low	Streak calendars; weekly summary reports
Prompt barrier identification; relapse prevention	Very low	Rarely implemented; a principal gap for maintenance

Behaviour change technique	Frequency	Function and design correlate
Plan social support; social comparison	Very low	Family or classroom co-play; leaderboards (largely unexploited)

Frequencies as reported by Moreira et al. across the studies coded in their scoping review [18].

4. Modalities of Gamified Delivery in Paediatric Dentistry

Gamification reaches the paediatric patient through a widening range of vehicles. The following taxonomy proceeds from the most heavily researched to the least, and, where evidence permits, notes the distinctive contribution and limitation of each.

4.1 Mobile health applications

Smartphone and tablet applications constitute the dominant modality, accounting for the majority of interventions in both the scoping and systematic literature [17, 18]. Their appeal is structural: they are available at the point and moment of behaviour, they can deliver reminders, they can capture longitudinal data, and their marginal cost of distribution is negligible.

The most rigorous appraisal of the commercial landscape remains that of Fijačko and colleagues, who screened 612 applications retrieved from six stores and found that only 17 satisfied minimal criteria for inclusion of gamification features and evidence-based content [19]. Quality assessed with the user version of the Mobile Application Rating Scale (uMARS) was on average good (mean overall quality 4.30 of 5), yet perceived impact was appreciably lower (3.58) and, critically, the information-quality domain could not be scored at all in seven of the seventeen applications because no verifiable health information was provided [19, 44, 45]. Independent evaluations have reached similar conclusions: Parker and colleagues found the available patient-facing oral hygiene applications heavily weighted towards timing and self-monitoring at the expense of technique instruction [40]; Sharif and Alkadhimi identified only a minority that addressed interdental cleaning, post-brushing rinsing or fluoride concentration [41]; Hotwani and colleagues found information provision, goal setting and feedback common but the underlying content unreferenced [42]; and Meriç, applying the Mobile Application Rating Scale to children's oral hygiene applications, again documented a divergence between engagement quality and information quality [43, 47]. Underwood and colleagues had earlier shown that a mobile application could successfully motivate evidence-based oral hygiene behaviour, establishing the principle before the commercial market outpaced its evidence base [46], and a subsequent systematic review of mobile health applications for children's oral health reached conclusions consistent with those above [81].

Effectiveness evidence for applications is nonetheless encouraging where a gamified version has been compared with a non-gamified equivalent rather than with no intervention. Zolfaghari and colleagues randomised mothers of preschool children to a simple informational application or to a gamified version of the same content; both improved maternal knowledge and practice, but plaque control in the children was significantly superior in the gamified arm after only one month [23]. The same group subsequently confirmed the benefit of maternal smartphone application use on early childhood oral health determinants in a paediatric dental setting [72]. Chen and colleagues report that regular use rates reached 72.4% in a gamified application group compared with 48.3% in a non-gamified comparator — an engagement differential that is arguably the single most important mechanistic finding in this literature, because engagement is the necessary condition for any downstream clinical effect [17].

More recently, Tahani and colleagues evaluated Happy Teeth, a Unity-developed gamified application combining mini-games, quizzes and a tower-defence mechanic, in a single-blind controlled trial among

8–9-year-old Iranian schoolchildren; both arms received one session of standard education, and the intervention arm additionally used the game over three to four weeks, with knowledge, Quigley–Hein plaque index, dietary behaviour and self-reported practices assessed at baseline and at three months [36]. Trials of this design — gamified adjunct versus standard education alone, with a clinical endpoint and blinded assessment — represent the methodological standard the field should now adopt.

4.2 Sensor-linked and "smart" toothbrushes

A distinct and mechanistically important subclass couples the game to an instrumented toothbrush, so that the reward is contingent not on self-report but on measured brushing behaviour. Alkilzy and colleagues demonstrated in a randomised controlled trial that a smartphone application paired with a brushing sensor significantly improved brushing performance and health indices [39]. Scheerman and colleagues, in the WhiteTeeth trial, showed improvements in oral hygiene among adolescents with fixed orthodontic appliances, a group in whom plaque control is both critical and characteristically poor [48]. Jacobson and colleagues, in a single-arm pre–post pilot, documented improved brushing duration and distribution associated with a mobile game application [50]. Zotti and colleagues similarly reported improved compliance in adolescent orthodontic patients [49].

The theoretical significance of sensor coupling is that it closes the feedback loop with objective data, converting "provide feedback on performance" from an aspiration into a measurable technique, and it defends against the principal validity threat in this literature — reliance on self-reported brushing. Its practical significance is more equivocal: France and colleagues, evaluating a smart toothbrush in children with autism spectrum disorder, found that despite improvements in brushing frequency and quality, caregivers reported recurrent technical difficulty in maintaining connectivity between brush and application and in accurately recording brushed areas [76]. Hardware dependence also imports cost, and thereby inequity.

4.3 Serious games and video games

Serious games occupy the space between education and entertainment, and are the modality with the longest pedigree in dentistry. The scoping review by Zaror and colleagues remains the most comprehensive synthesis, encompassing games developed both for the training of oral health professionals and for health promotion, and concluding that although the concept is promising the quality of the underlying evidence has generally been low [21].

Within paediatric oral health specifically, the work of Aljafari and colleagues is the most methodologically developed. Their computer game intervention for high-caries-risk children and their parents improved dietary knowledge and toothbrushing and dietary practices in a randomised controlled trial [51], and a subsequent school-based randomised trial of a video-game intervention demonstrated a significant reduction in plaque scores [52]. Mendonça and colleagues have illustrated the value of user-centred design methodology in serious game development, involving children directly in the iterative design process rather than treating them as passive recipients [53]. Reynolds and colleagues, examining a serious game intended to prepare children for tooth extraction under general anaesthesia, provided an instructive counter-example: family and clinical predictors of non-compliance were substantial, demonstrating that even a well-constructed game will fail if the family context is not addressed [54].

4.4 Augmented and virtual reality

Augmented reality superimposes game content on the real oral environment, and is conceptually attractive because it gamifies the actual behaviour rather than a screen-based proxy. Dey and colleagues reported, using fluorescence-based assessment, that an augmented reality-assisted toothbrush produced a significant reduction in bacterial counts compared with conventional manual brushing in 6–8-year-old children [55]. Amantini and colleagues have published a development protocol for an augmented reality serious game to motivate oral hygiene practice [56], and Lin and colleagues demonstrated in health education more broadly that incorporating augmented reality into a board game significantly improved learning motivation and acceptance [57]. Kang and colleagues used a Kinect-based gesture-recognition game to teach oral hygiene to children with intellectual disability, reporting improved brushing independence and skill retention [58]. Chen and colleagues identified augmented reality, alongside mobile applications, as the technology associated with the most consistent improvements in their systematic review [17].

Virtual reality has been used predominantly for procedural distraction and anxiety control rather than for hygiene education, and although effective in that role it falls outside the scope of gamified behaviour change unless a game element is intrinsic. An instructive hybrid is the dental simulation game evaluated by Karkoutly and colleagues, which reduced pain and anxiety during primary molar pulpotomy compared with the tell–show–do technique [59] — evidence that gamification may serve behaviour guidance in the operatory as well as prevention at home, and a plausible digital extension of the established non-pharmacological techniques set out in professional behaviour guidance recommendations [86].

4.5 Conversational agents and chatbots

Conversational agents represent the newest modality and the one most likely to be transformed by contemporary language models. Chang and colleagues developed a gamified chatbot for the promotion of oral self-care in Taiwanese children, deriving its architecture explicitly from the Behaviour Change Wheel and COM-B model and incorporating quizzes, dialogue menus and motivational prompts; usability testing yielded a mean score of 79.91 out of 100, indicating strong acceptability [24]. The distinctive affordance of the conversational modality is responsiveness to the individual child's stated barriers — precisely the behaviour change technique (barrier identification) that is most conspicuously absent from conventional applications. The corresponding risk is that a generative agent may produce plausible but clinically incorrect advice, which places an unusually high premium on clinician oversight and content constraint.

4.6 Non-digital gamification

It should not be assumed that gamification requires a screen. A substantial and largely Indian and Chinese literature has evaluated analogue game formats, which have the considerable advantages of negligible cost, immunity to digital exclusion, and natural suitability for the classroom.

Kumar and colleagues demonstrated in a randomised controlled trial that game-based teaching improved oral health status compared with conventional teaching [60]. Malik, Kumar and colleagues reported superior knowledge and oral hygiene status with game-based education [61], as did Maheswari and colleagues in a prospective comparison [62]. GeethaPriya and colleagues found a modified snakes-and-ladders board game to be as effective as the flashcard method in improving oral health behaviour and practice [63]. Shi and colleagues evaluated a "dental truth or dare" board game in preschool children with improvements in both knowledge and hygiene status [64]. Kashyap and colleagues, in a field trial in Lucknow, demonstrated the effectiveness of a game-based method on oral hygiene performance in twelve-year-olds [66], and Santhosh and colleagues reported benefit from a puzzle-solving game assisted by visual aids in a single-blind randomised trial among adolescents [67]. Saraf and colleagues showed that an educational game altered preference toward non-cariogenic food items in preschool children, extending gamification beyond hygiene into dietary counselling [68]. Sharma and colleagues found game-based and self-made storybook formats both superior to conventional education in a prospective cohort [69], and Sharififard and colleagues demonstrated, in a cluster randomised trial, that a music- and game-based programme was effective in visually impaired schoolchildren — an important demonstration that gamification can be adapted to sensory impairment [65]. Mukhi and colleagues found both cartoon video animation and a connect-the-dots game effective in improving knowledge, attitude and oral hygiene status in 7–10-year-olds [71], and Shirahmadi and colleagues showed that explicitly theory-based educational interventions outperformed atheoretical ones among elementary school students — a finding that anticipates the argument of Section 3 [70].

4.7 Classroom-based interactive quiz and visual performance platforms

A hybrid modality of particular relevance to school dental programmes combines animated audiovisual content, a live interactive quiz platform and hands-on demonstration. The interactive game-based visual performance (IGVP) technique evaluated by Kumar and colleagues in a single-blinded randomised controlled trial in Belagavi, Karnataka, is the clearest exemplar and merits detailed consideration because it reports the largest clinical effect in the paediatric gamification literature [22]. One hundred children aged 12–15 years were randomised to conventional oral health education or to IGVP, the latter comprising a 5.94-minute customised animated video, a 30-minute Kahoot-based question-and-answer session, and individual demonstration and practice of the modified Bass technique on a tooth model. At three months, the IGVP group showed a 58.7% reduction in mean gingival score and a 63.4% reduction in mean plaque score, against 2.8% and 0.7% respectively in the control group, with knowledge gain of 22.4% versus 7.8% ($p < 0.001$) [22].

Two features of this trial deserve emphasis. First, the intervention was multi-component, coupling gamified instruction to supervised psychomotor practice; the magnitude of the effect should therefore not be attributed to the game element alone. Second, the control condition was a single fifteen-minute health talk, and the near-zero improvement in that arm is itself a striking indictment of conventional practice.

5. Evidence of Effectiveness

Table 3 summarises the principal primary studies and syntheses that inform this review. The evidence is examined below by outcome domain.

Table 3: Summary of Key Studies on Gamification in Paediatric Oral Health

Study (year)	Design	Population	Intervention / comparator	Principal findings
Kumar et al. (2022) [22]	Single-blind RCT, 3-month follow-up	100 children, 12–15 y, India	Interactive game-based visual performance (animated video + Kahoot quiz + brushing demonstration) vs 15-min conventional health talk	Plaque score ↓63.4% and gingival score ↓58.7% vs 0.7% and 2.8% in control; knowledge gain 22.4% vs 7.8% (p<0.001)
Zolfaghari et al. (2021) [23]	RCT, 1 month	Mothers of preschoolers, Iran	Gamified mHealth app vs simple informational app	Both improved maternal knowledge and practice; children's plaque control

Study (year)	Design	Population	Intervention / comparator	Principal findings
				significantly superior in gamified arm (p<0.05)
Tahani et al. (2025) [36]	Single-blind controlled trial, 3 months	8–9 y schoolchildren, Iran	"Happy Teeth" gamified app + standard education vs standard education alone	Assessed knowledge, Quigley–Hein plaque index, dietary behaviour and self-reported practice; adjunctive gamification favoured
Aljafari et al. (2022) [52]	RCT, school-based	Primary school children, Jordan	Video-game-based oral health intervention vs conventional	Significant reduction in plaque scores
Aljafari et al. (2017) [51]	RCT	High-caries-risk children and parents, UK	Computer game-based education	Improved dietary knowledge, toothbrushing and dietary practice
Alkilzy et al. (2019) [39]	RCT	Children	Smartphone app + brushing sensor	Significant improvement in brushing performance and health indices
Dey et al. (2023) [55]	Comparative clinical study	6–8 y children, India	Augmented reality-assisted toothbrush vs manual brushing	Significant reduction in bacterial count on fluorescence-based assessment (p<0.05)
Chang et al. (2024) [24]	Development and usability study	Children, Taiwan	Gamified chatbot built on Behaviour Change Wheel / COM-B	Mean usability score 79.91/100; high acceptability and likeability
Sharififard et al. (2020) [65]	Cluster RCT	Visually impaired schoolchildren, Iran	Music- and game-based oral health education	Significant improvement in oral health outcomes; demonstrates adaptability to sensory impairment
Karkoutly et al. (2024) [59]	RCT	Children undergoing pulpotomy, Syria	Dental simulation game vs tell–show–do	Reduced pain and anxiety during primary molar pulpotomy
Fijačko et al. (2020) [19]	Systematic app-store	17 of 612 apps screened	Gamification taxonomy, evidence-	Mean 6.87/31 gamification features; time pressure 94%,

Study (year)	Design	Population	Intervention / comparator	Principal findings
	search and appraisal		based dentistry criteria, uMARS	virtual characters 82%, fantasy 76%; mean app quality 4.30/5 but perceived impact 3.58
Moreira et al. (2024) [18]	Scoping review (15 studies)	Children and adolescents	Gamification mechanisms and behaviour change techniques	73% of apps evidence-based; brushing time defined in 100%, daily brushing amount in 91%; tongue cleaning and brush grip never mentioned
Patil et al. (2024) [20]	Systematic review of RCTs	Children 4–12 y	Game-based vs conventional teaching	Game-based teaching consistently superior for knowledge, plaque levels and compliance
Chen et al. (2025) [17]	Systematic review (41 studies)	Children ≤18 y	Digital and non-digital gamified interventions	Digital interventions outperformed non-digital; regular use 72.4% vs 48.3%; 95% of studies at moderate risk of bias
Pisano et al. (2025) [25]	Narrative review (6 studies)	207 children (173 ASD, 34 Down syndrome)	Dental m-health apps, interactive and passive	Improved brushing skill, autonomy and cooperation; reduced anxiety; app availability for SHCN limited

RCT, randomised controlled trial; ASD, autism spectrum disorder; SHCN, special healthcare needs; uMARS, user version of the Mobile Application Rating Scale.

5.1 Clinical outcomes: plaque, gingival health and caries

Plaque and gingival indices are the outcomes most consistently reported and the ones on which the case for gamification principally rests. The largest reported effect remains that of Kumar and colleagues, with a 63.4% reduction in plaque score and 58.7% reduction in gingival score at three months against negligible change in the conventionally educated control group [22]. Zolfaghari and colleagues reported significantly superior plaque control in children of mothers using a gamified rather than a simple application after one month [23]. Aljafari and colleagues demonstrated significant plaque reduction following a school-based video-game intervention [52]. Dey and colleagues showed reductions in bacterial load with an augmented reality-assisted brush [55]. Krishnan and colleagues, in adolescents with autism spectrum disorder, reported a fall in plaque index from 2.01 (±0.06) at baseline to 1.00 (±0.00) at six weeks and 0.46 (±0.11) at twelve weeks, with gingival index falling from 1.03 (±0.17) to 0.58 (±0.16) and then 0.24 (±0.11), effects statistically indistinguishable from conventional visual pedagogy [73].

The systematic review by Patil and colleagues concluded that game-based teaching consistently produced lower plaque levels and better compliance than conventional education across the randomised trials examined [20], and Chen and colleagues reached a concordant conclusion across 41 studies [17]. Two caveats temper this consistency. First, no study in this literature has demonstrated a reduction in caries increment, which is the outcome of ultimate public health interest; plaque and gingival indices are surrogates, and the interval over which they have been measured is far shorter than the interval over which caries develops. Second, the largest effects derive from multi-component interventions in which supervised toothbrushing practice was delivered alongside the game, so the independent contribution of gamification cannot be isolated.

5.2 Knowledge and oral health literacy

Knowledge gain is the most reliably demonstrated outcome, and also the least clinically meaningful in isolation. Kumar and colleagues recorded a 22.4% knowledge gain in the gamified arm against 7.8% in the control arm, with post-intervention mean scores of 8.94 (±1.27) and 7.88 (±1.97) respectively ($p < 0.001$), and item-level analysis showing the largest gains for toothbrush replacement interval, brushing frequency and brushing technique — domains in which baseline knowledge was poorest [22]. Comparable findings have been reported for crossword and quiz formats [66], snakes-and-ladders adaptations [63], storybook formats [69] and cartoon-animated audiovisual aids. Chen and colleagues found improvements in knowledge and behaviour in 38% of the experimental studies reviewed, with digital interventions outperforming non-digital [17].

Item-level analysis in the trial by Kumar and colleagues carries a lesson that is easily overlooked: several knowledge items showed high baseline accuracy in both groups — those concerning the choice of dentifrice, rinsing after meals and periodic dental visits — which the authors attributed to prior classroom teaching and to commercial advertising [22]. Gamified education adds most where baseline knowledge is weakest and where the content is procedural rather than declarative. Interventions should therefore be targeted at demonstrated deficits rather than delivering undifferentiated content.

5.3 Behavioural outcomes

Brushing duration and frequency are the behaviours most directly targeted. Jacobson and colleagues documented increased brushing duration associated with a mobile game application [50]; sensor-coupled studies have demonstrated improvements in both duration and distribution across the dentition [39, 48]; and Kang and colleagues reported enhanced brushing independence and skill retention following a gesture-based motion-capture game in children with intellectual disability [58]. Practice-level improvements documented in the trial by Kumar and colleagues extended beyond brushing to the adoption of dental flossing (from 20.8% to 83.3% in the intervention group, $p < 0.001$) and tongue cleaning (from 29.2% to 87.5%, $p < 0.001$), against non-significant changes in the control group [22]. Dietary behaviour has been targeted less often but successfully, both by Aljafari and colleagues [51] and by Saraf and colleagues, whose educational game shifted preference toward non-cariogenic food items in preschool children [68].

The critical unresolved question is durability. Almost all behavioural outcomes have been assessed within one to three months of intervention, and the few studies that have examined longer intervals report attenuation. Both Moreira and colleagues and Chang and colleagues note the decline in engagement once novelty has passed [18, 24], and Chen and colleagues found that 24% of studies lacked any long-term follow-up at all [17].

5.4 Engagement, motivation and psychological outcomes

Engagement is the mediator through which all other effects operate, and it is here that gamification demonstrates its clearest superiority. The differential reported by Chen and colleagues — 72.4% regular use in a gamified application group against 48.3% in a non-gamified group — quantifies an effect that is otherwise described only qualitatively [17]. Children consistently report higher satisfaction with game-based learning than with non-interactive instruction [18], and caregivers report that oral hygiene routines become less stressful and more autonomous [25].

Anxiety reduction is a second psychological benefit, of particular relevance to paediatric dentistry. Applications that familiarise the child with the dental environment through social stories, previews of the surgery and staff, and step-by-step procedural videos have been associated with reduced dental fear, both by self-report and, in some studies, by objective measures including electrocardiographic and galvanic skin response parameters [25]. The dental simulation game evaluated by Karkoutly and colleagues reduced procedural pain and anxiety relative to tell–show–do [59].

5.5 Caregiver and family outcomes

In children below approximately eight years of age, the caregiver is the effective agent of oral hygiene, and interventions that target the parent rather than the child have a strong rationale. Zolfaghari and colleagues demonstrated that a gamified application directed at mothers improved maternal knowledge and practice and produced measurable plaque reduction in their children [23], a finding replicated in a paediatric dental setting [72]. Chen and colleagues found substantial improvements in parental engagement and awareness in the non-experimental literature, translating into better brushing habits and increased preventive dental attendance, with 58.8% of caregivers reporting that their children brushed more often when using gamified applications [17]. Borrelli and colleagues, in a large randomised clinical trial, demonstrated the effectiveness of parent-targeted oral health text messaging for underserved children attending paediatric clinics — a low-technology, high-reach model that deserves closer attention as a scalable complement to application-based approaches [79]. A dedicated systematic review of application-based interventions targeting the modifiable risk factors for early childhood caries similarly concluded that parent-directed digital tools can shift the determinants of disease, while noting the same deficits of trial quality and follow-up identified throughout this review [80].

5.6 Children with special healthcare needs

Children with special healthcare needs experience a disproportionate burden of untreated caries and periodontal disease, driven by sensory aversion to toothpaste texture and taste and to brush pressure, by communication and behavioural difficulties, by caregiver apprehension, and by the limited experience of many practitioners in adapting the dental environment [25]. The predictability, visual structure and repetition intrinsic to gamified tools align unusually well with the learning characteristics of this population.

Pisano and colleagues reviewed six studies encompassing 207 children, of whom 173 had autism spectrum disorder and 34 had Down syndrome, aged between 4 and 16 years with a mean of 10.68 years [25]. Interventions ranged from 28 to 240 days. Applications aimed at toothbrushing skill — the "Brush Up" avatar-guided application evaluated by Krishnan and colleagues [73], the "çATED" pictogram-based iPad programme evaluated by Lopez Cazaux and colleagues [74], and the smart toothbrush studied by France and colleagues [76] — improved brushing quality, frequency and autonomy, with fewer steps of the routine omitted. Applications aimed at familiarisation and behaviour management — the "My Dentist" web application combined with an information and communication technology programme studied by Narzisi and colleagues [75], and the caregiver-focused resource developed by Tan and colleagues [77] — improved cooperation during treatment and caregiver awareness. A single study in Down syndrome, using the "Gigiku Sehat" application, improved oral health knowledge [25].

Three observations follow. First, both interactive and passive engagement formats were effective, and for some children the decomposition of brushing into discrete pictorial sub-tasks (passive engagement) was more appropriate than a game requiring rapid response. Second, interventions targeting psychomotor skill required substantially longer exposure than those targeting knowledge, consistent with the greater demands of motor planning and automation. Third, the evidence base is confined almost entirely to autism spectrum disorder and Down syndrome; children with sensory impairment, cerebral palsy or other conditions are essentially unstudied, with the notable exception of the cluster randomised trial in visually impaired children by Sharififard and colleagues [65] and the Kinect-based work of Kang and colleagues in intellectual disability [58]. A broader scoping review of gamification in mobile applications for children with disabilities confirms both the promise and the narrowness of the current evidence [78].

5.7 Strength and consistency of the evidence

The direction of effect across this literature is remarkably consistent: in virtually every comparison, gamified education equals or exceeds conventional education, a pattern that also holds across the wider field of behaviour change interventions for paediatric oral health promotion [82]. Consistency of direction is not, however, equivalent to strength of evidence, and four limitations require candid acknowledgement. First, methodological quality is modest. Chen and colleagues assessed 39 of 41 studies (95%) as carrying a moderate risk of bias, principally arising from reliance on self-reported outcomes, variation in intervention adherence and heterogeneity of measurement [17]. Second, blinding is intrinsically difficult: participants cannot be masked to whether they are playing a game, and although outcome assessors were blinded in the better trials [22], performance and detection bias cannot be eliminated. Third, follow-up is short, rarely exceeding three months, so that reported effects may reflect the novelty period rather than durable behaviour change. Fourth, heterogeneity of intervention content, comparator and outcome instrument precludes pooling and makes it impossible to determine which specific game elements are responsible for effect — the central question for design. Publication bias must also be presumed, since interventions developed by their own evaluators are unlikely to be reported when unsuccessful.

6. Testing the Design–Content Inversion

A gamified tool can be highly engaging and clinically incomplete. The separation of engagement quality from information quality is the most important single finding of the application-evaluation literature, and this section examines it in order to test Proposition 1: that the clinical content present in these tools correlates with its gamifiability rather than with its preventive importance.

Fijačko and colleagues assessed ten evidence-based dentistry content items across four stages of the brushing episode and found that applications contained, on average, approximately three of the ten [19]. Brushing time was the near-universal item, present in 94% of applications, of which 82% set the target at two minutes; one application set it at one minute and two at three minutes. Beyond timing, coverage collapsed: fewer than 20% addressed dental floss or other interdental aids; none promoted the sequence of flossing before brushing; only two visualised the correct pea-sized quantity of fluoride toothpaste; over one-third specified no brushing technique at all, and where a technique was specified the scrub method predominated (29%) rather than the modified Bass technique that is generally recommended for its plaque removal efficiency [19, 83]. Moreira and colleagues reached parallel conclusions: brushing time was defined in 100% and daily brushing amount in 91% of the evidence-based applications examined, but spitting out toothpaste appeared in only one application (8%), and tongue cleaning and toothbrush grip were never mentioned at all [18].

These distributions are not random, and they do not track clinical importance. Interdental cleaning, correct dentifrice quantity and the avoidance of post-brushing rinsing are all supported by evidence at least as strong as that for two-minute brushing, yet all three are rare or absent while brushing time is near-universal. What the present items share is not preventive weight but mechanical convenience. Brushing time is trivially easy to gamify — it maps directly onto a timer, which maps directly onto time pressure, the single most prevalent game element. Toothbrush grip, interdental technique and post-brushing rinsing behaviour are difficult to represent as game mechanics, and so they are omitted. The design vocabulary is silently determining the clinical content, which is precisely the inversion of the correct order. Furthermore, the majority of applications are developed by small enterprises without dental input; Fijačko and colleagues found that 82% of the applications they reviewed were produced by small and medium-sized enterprises and only 12% by healthcare-related agencies [19].

Three consequences follow for the profession. Dental input must occur at the design stage rather than as post hoc endorsement; content must be explicitly referenced to guideline sources, so that a fluoride concentration recommendation can be traced to a Cochrane review rather than to a marketing department [84]; and paediatric dentists should be able to appraise applications competently before recommending them, for which validated instruments such as the Mobile Application Rating Scale and its user version provide a practical framework [44, 45, 47, 85].

Proposition 1 is therefore supported. The content of gamified paediatric oral health tools is being selected by the expressive capacity of the available game mechanics rather than by the requirements of preventive dentistry. The remedy is not to add more content to existing designs but to reverse the order of construction: to specify the clinical curriculum first and then to engineer mechanics capable of carrying its difficult elements. Toothbrush grip can in principle be taught through camera-based or haptic feedback; interdental cleaning can be sequenced as a progressive unlock; dentifrice quantity can be visually calibrated. That none of these has been widely attempted reflects the absence of clinical governance at the design stage, not any intrinsic limitation of the medium.

7. Barriers, Challenges and Unresolved Problems

Table 4 sets out the principal barriers to the effective deployment of gamification in paediatric oral health, with proposed mitigation. Each is discussed below.

7.1 Absence of standardisation and validation

That only 17 of 612 screened applications met minimal evidence-based criteria is the starkest available statistic in this field [19]. There is at present no certification pathway, no minimum content standard and no requirement for clinical validation before an application marketed for children's oral health reaches an application store. Engagement is optimised because engagement drives downloads; clinical accuracy is not, because it does not.

7.2 The novelty problem: initiation versus maintenance

Gamification reliably initiates behaviour and much less reliably maintains it. As argued in Section 3.3, this is predictable from the behaviour change techniques actually embedded: those that establish behaviour are abundant, those that maintain it are scarce. Both Moreira and colleagues and Chang and colleagues describe engagement decay once novelty passes [18, 24]. Design responses — evolving challenges, seasonal content, escalating difficulty, social features, and periodic content refresh — are well established in commercial game design but have almost never been implemented, let alone evaluated, in this domain.

7.3 Digital inequity

The populations with the greatest burden of untreated caries are, in general, those with the least reliable access to smartphones, data connectivity and caregiver digital literacy. A gamified intervention distributed through an application store may therefore widen rather than narrow the oral health gradient — an inverse care law operating through technology. Mitigations include school-based deployment on institutionally owned devices, offline-capable design, low-bandwidth and low-specification builds, provision in local languages, and retention of validated non-digital formats such as board games and puzzles for settings where digital delivery is not feasible [63, 64, 66, 67]. Text-message-based approaches, as evaluated by Borrelli and colleagues, offer a further low-barrier route [79].

7.4 Generic and developmentally inappropriate design

An application that engages a twelve-year-old is unlikely to engage a four-year-old, and one designed for a neurotypical child may be actively aversive to a child with sensory sensitivity. Pisano and colleagues emphasise the necessity of customisable, sensory-sensitive features — adjustable colour schemes, optional sound and vibration, choice between verbal and touch command, subtitle options and selectable background music [25]. Most commercial applications offer none of these.

7.5 Weak integration with the dental home

Gamified tools operate almost entirely outside formal dental care. They are seldom linked to the child's clinical record, to individualised risk assessment, to post-operative instruction or to recall scheduling, and the dentist typically has no visibility of adherence data that the application is already collecting. This disconnection wastes the principal informational advantage of the digital modality and confines these tools to the status of consumer products rather than clinical adjuncts.

7.6 Ethical, privacy and screen-time considerations

Applications directed at minors routinely collect behavioural data, and the governance of that data is frequently opaque. Compliance with data protection frameworks such as the General Data Protection Regulation requires explicit and verifiable informed consent from a parent or legal guardian, purpose limitation and secure storage [25]. Commercial considerations introduce further hazard: Fijačko and colleagues documented in-app purchases in five of seventeen applications, freemium and free-trial monetisation, and advertisement within applications aimed at children, with only one application alerting users that real money was required for in-app purchases [19]. Given that the preadolescent brain is still developing in respect of reasoning and anticipation of future consequences, the deliberate use of affective game states to drive expenditure in this population is ethically indefensible. Finally, cumulative screen exposure is a legitimate parental concern, although the daily exposure required by these tools — typically under ten minutes — is small relative to overall paediatric screen use [19].

Table 4: Barriers to Implementation of Gamification in Paediatric Oral Health and Proposed Mitigation

Barrier	Manifestation	Proposed mitigation
Lack of standardisation and clinical validation	Only 17 of 612 screened apps met minimal evidence-based criteria; 82% developed by enterprises without dental input	Professional body certification or endorsement scheme; mandatory referencing of content to guideline sources; dental co-design from inception
Engagement decay after novelty	Interest declines once content is exhausted; maintenance-oriented behaviour change techniques largely absent	Embed relapse prevention, barrier identification, self-monitoring and social support; evolving challenges and periodic content refresh
Digital inequity	Device, connectivity and literacy barriers concentrated in highest-need populations	School-based deployment on shared devices; offline and low-bandwidth builds; local-language versions; retain validated non-digital formats; SMS-based alternatives
Generic, developmentally inappropriate design	One design serves all ages and neurotypes; sensory-sensitive options rare	Age-banded content; customisable colour, sound, vibration, input mode and subtitles; co-design with children and caregivers
Poor integration with clinical care	Tools not linked to records, risk assessment, recall or post-operative instruction	Two-interface architecture (family and clinician); adherence data visible at review; app prescription as part of the preventive plan
Ethical and privacy concerns	Opaque data governance; in-app purchases and advertising directed at minors	GDPR-compliant verifiable parental consent; prohibition of in-app purchase and advertising in child-directed oral health tools; transparent data policies
Weak evidence base	95% of studies at moderate risk of bias; follow-up rarely beyond 3 months; no caries endpoints	Adequately powered RCTs with ≥12-month follow-up; blinded assessors; core outcome set; registration and reporting to CONSORT

8. Towards Clinical Integration: A Proposed Framework

The evidence reviewed above supports a shift in the framing of gamification from an interesting adjunct to a component of the preventive care pathway. The following framework is proposed as a practical structure for integration, organised around the four principles of predictive, preventive, personalised and participatory care and drawing on the multi-interface architecture proposed by Pisano and colleagues [25].

8.1 Prescription rather than recommendation

A gamified tool should be selected and prescribed in the same manner as a fluoride regimen: on the basis of an individual caries risk assessment, with a specified indication, an expected duration of use and a review point. Selection should be informed by a structured appraisal of content quality and gamification adequacy rather than by store ratings, which have been shown to diverge significantly from formally assessed quality [19].

8.2 A two-interface architecture

Pisano and colleagues propose an application with distinct family and clinician interfaces sharing a common structure, in which the caregiver can record the child's sensory profile and previous dental experience, upload intraoral photographs for remote review, and monitor adherence, while the clinician can upload personalised content — images of the surgery and staff, videos of the specific procedure the child will undergo — and view adherence data at the review appointment [25]. This architecture converts the application from a consumer product into a communication channel, and directly addresses the integration deficit described in Section 7.5; it also aligns gamified prevention with the broader movement towards telematic paediatric oral health services [87].

8.3 Staged deployment across the care pathway

- Before the first visit: familiarisation content, social stories and previews of the environment, particularly for anxious children and those with special healthcare needs.
- At the preventive visit: prescription of a validated brushing application with sensor coupling where affordable, calibrated to the child's age and risk profile, alongside supervised psychomotor practice — the combination that produced the largest reported clinical effects [22].
- Between visits: adherence tracking, reminders and caregiver support, with escalation to the clinician where adherence falls.
- Before an operative procedure: procedure-specific preparatory content and, where indicated, a simulation game as an adjunct to behaviour guidance [59].
- At the school or community level: classroom-based interactive quiz and visual performance formats, or validated non-digital games where digital delivery is impractical [22, 63, 64, 66].

8.4 The caregiver as co-target

In children under eight years of age the caregiver should be treated as the primary behavioural target rather than as a facilitator, on the evidence that maternal-directed gamified education produces measurable plaque reduction in the child [23, 72] and that caregiver engagement predicts preventive attendance [17, 79].

9. Priorities for Future Research

1. Long-term efficacy. Adequately powered randomised controlled trials with follow-up of at least twelve months, and preferably twenty-four, are the single most important requirement. Until durability is established, all present claims are claims about the novelty period.

2. Caries as an endpoint. No study to date has demonstrated a reduction in caries increment. Trials of sufficient duration and size to detect a difference in DMFT/dmft increment or in the incidence of new lesions are required before public health investment can be justified on preventive grounds.
3. Dismantling designs. Factorial or component-network trials are needed to determine which game elements are active. The present literature can state that gamified interventions work; it cannot state which part of them works.
4. A core outcome set. Heterogeneity of measurement is the principal obstacle to pooling. A consensus core outcome set for paediatric oral health behaviour interventions — specifying plaque and gingival indices, a standardised knowledge instrument, objective brushing metrics and an engagement measure — would transform the cumulability of this evidence.
5. Theory-driven maintenance design. Interventions should be built to include the maintenance-oriented behaviour change techniques currently absent, and these should be evaluated specifically against engagement decay.
6. Under-studied populations. Children with sensory impairment, cerebral palsy, attention deficit hyperactivity disorder and intellectual disability beyond Down syndrome are essentially unrepresented, as are children in low-resource and rural settings and non-English-language populations.
7. Economic evaluation. Cost-effectiveness analysis is almost entirely absent. Given that the case for gamification rests substantially on scalability, the absence of cost data is a material gap.
8. Generative conversational agents. Large language model-based agents offer unprecedented personalisation and the capacity to address individual barriers, but require rigorous evaluation of clinical accuracy, safety and safeguarding before deployment to children.

10. Limitations of This Review

This is a narrative rather than a systematic review, and the selection of studies, although guided by an explicit search strategy and eligibility criteria, was not conducted in duplicate and did not incorporate formal risk-of-bias assessment of individual studies; some degree of selection bias is therefore possible. Restriction to English-language, peer-reviewed publications will have excluded relevant work, particularly from Latin America, China and the Middle East. No quantitative synthesis was undertaken, so the magnitudes reported are those stated by original authors and are not directly comparable across studies. The rapidly evolving nature of both the technology and the commercial application landscape means that specific application evaluations date quickly. Finally, this review inherits the limitations of the primary literature it summarises, most notably short follow-up and the absence of caries endpoints.

Its strengths are the integration of behavioural theory with design taxonomy and measured outcome, the inclusion of both digital and non-digital modalities, the explicit attention to children with special healthcare needs, and the candid appraisal of content quality and methodological weakness.

11. Conclusion

That gamification engages children more effectively than didactic instruction is no longer in serious doubt. Across randomised trials and three recent syntheses, gamified education equals or exceeds conventional teaching with striking consistency, producing plaque score reductions of up to 63.4%, gingival score reductions of up to 58.7%, knowledge gains approximately three times those of a conventional health talk, substantially higher rates of sustained engagement, and measurable benefit for children with special healthcare needs and their caregivers. Its grounding in Self-Determination Theory and the COM-B framework is sound, and the mechanisms through which it acts address precisely the deficits that render didactic education ineffective.

The argument of this review is that these tools are nevertheless engaging but incomplete, and that both the incompleteness and the impermanence follow from a single structural fault. The clinical content that survives into a gamified tool is the content that a game mechanic can conveniently express: brushing time, which is a timer, appears almost everywhere, while toothbrush grip, interdental sequence, dentifrice quantity, spitting without rinsing and tongue cleaning — none of which is a timer, or a point, or a badge — appear almost nowhere. In parallel, the behaviour change techniques that survive are those that start a behaviour, not those that sustain one, which is why engagement decays on a schedule that the field continues to report as a limitation of its evidence rather than as a property of its designs. In both cases the medium is choosing the message.

The correction is conceptually simple and organisationally difficult. Clinical requirements must be specified before mechanics are chosen, and mechanics must then be engineered to carry the difficult content rather than the convenient content — grip taught through haptic or camera-based feedback, interdental cleaning through sequenced unlocking, dentifrice quantity through visual calibration. Maintenance-oriented behaviour change techniques must be deliberately built in rather than left to emerge. Dental input must occur at inception rather than as post hoc endorsement, and the resulting tools must be integrated with the dental home so that the adherence data they already collect informs clinical decisions. Design must begin from the child who has the least rather than the most.

Until this inversion is reversed, further trials demonstrating three-month plaque reduction will confirm what is already known while leaving the substantive problem untouched. Gamification will not replace the paediatric dentist, the fluoride, or the supervised toothbrushing lesson. Properly constructed, it extends each of them into the twenty-three hours of the day during which the child is not in the dental chair — and that, rather than any individual effect size, is why it warrants the profession's serious and critical attention.

12. Author Contributions

All authors have contributed equally to the conception and design of the study, data acquisition, analysis and interpretation of data, and drafting and critical revision of the manuscript. All authors have read and approved the final version of the manuscript submitted for publication.

References

1. World Health Organization, "Global Oral Health Status Report: Towards Universal Health Coverage for Oral Health by 2030", World Health Organization, Geneva, 2022.
2. M. Peres, L. Macpherson, R. Weyant, et al., "Oral Diseases: A Global Public Health Challenge", The Lancet, 2019, 394 (10194), 249-260.
3. E. Bernabe, W. Marcenes, C. Hernandez, et al., "Global, Regional, and National Levels and Trends in Burden of Oral Conditions from 1990 to 2017", Journal of Dental Research, 2020, 99 (4), 362-373.
4. P. Correa-Faria, A. Daher, M. Freire, et al., "Impact of Untreated Dental Caries Severity on the Quality of Life of Preschool Children and Their Families", Quality of Life Research, 2018, 27 (12), 3191-3198.
5. S. Jackson, W. Vann, J. Kotch, et al., "Impact of Poor Oral Health on Children's School Attendance and Performance", American Journal of Public Health, 2011, 101 (10), 1900-1906.

6. C. McGrath, H. Broder, M. Wilson-Genderson, "Assessing the Impact of Oral Health on the Life Quality of Children", Community Dentistry and Oral Epidemiology, 2004, 32 (2), 81-85.
7. S. Kwan, P. Petersen, C. Pine, et al., "Health-promoting Schools: An Opportunity for Oral Health Promotion", Bulletin of the World Health Organization, 2005, 83 (9), 677-685.
8. P. Nakre, A. Harikiran, "Effectiveness of Oral Health Education Programs: A Systematic Review", Journal of International Society of Preventive and Community Dentistry, 2013, 3 (2), 103-115.
9. M. Angelopoulou, K. Kavvadia, K. Taoufik, et al., "Comparative Clinical Study Testing the Effectiveness of School Based Oral Health Education Using Experiential Learning or Traditional Lecturing in 10 Year-old Children", BMC Oral Health, 2015, 15, 51.
10. N. Srivastava, "A Comparative Evaluation of Efficacy of Different Teaching Methods of Tooth Brushing in Children", Journal of Oral Hygiene and Health, 2013, 1, 118.
11. S. Deterding, D. Dixon, R. Khaled, et al., "From Game Design Elements to Gamefulness: Defining Gamification", Proceedings of the 15th International Academic MindTrek Conference, Association for Computing Machinery, 2011, 9-15.
12. K. Huotari, J. Hamari, "Defining Gamification: A Service Marketing Perspective", Proceedings of the 16th International Academic MindTrek Conference, Association for Computing Machinery, 2012, 17-22.
13. D. Johnson, S. Deterding, K. Kuhn, et al., "Gamification for Health and Wellbeing: A Systematic Review of the Literature", Internet Interventions, November 2016, 6, 89-106.
14. L. Sardi, A. Idri, J. Fernandez-Aleman, "A Systematic Review of Gamification in e-Health", Journal of Biomedical Informatics, 2017, 71, 31-48.
15. B. Cugelman, "Gamification: What It Is and Why It Matters to Digital Health Behavior Change Developers", JMIR Serious Games, 2013, 1 (1), e3.
16. R. Ryan, E. Deci, "Self-determination Theory and the Facilitation of Intrinsic Motivation, Social Development, and Well-being", American Psychologist, 2000, 55 (1), 68-78.
17. J. Chen, Y. Ying, M. Pang, et al., "The Application of Gamification in Children’s Oral Health Management: Systematic Review", Journal of Medical Internet Research, November 2025, 27, e75541.
18. R. Moreira, A. Silveira, T. Sequeira, et al., "Gamification and Oral Health in Children and Adolescents: Scoping Review", Interactive Journal of Medical Research, April 2024, 13, e35132.
19. N. Fijacko, L. Gosak, L. Cilar, et al., "The Effects of Gamification and Oral Self-care on Oral Hygiene in Children: Systematic Search in App Stores and Evaluation of Apps", JMIR mHealth and uHealth, July 2020, 8 (7), e16365.
20. S. Patil, F. Licari, S. Bhandi, et al., "Effect of Game-based Teaching on the Oral Health of Children: A Systematic Review of Randomised Control Trials", Journal of Clinical Pediatric Dentistry, July 2024, 48 (4), 26-37.
21. C. Zaror, R. Marino, C. Atala-Acevedo, "Current State of Serious Games in Dentistry: A Scoping Review", Games for Health Journal, April 2021, 10 (2), 95-108.
22. R. Kumar, A. Deshpande, A. Ankola, et al., "Effectiveness of a Visual Interactive Game on Oral Hygiene Knowledge, Practices, and Clinical Parameters among Adolescents: A Randomized Controlled Trial", Children, November 2022, 9 (12), 1828.

23. M. Zolfaghari, M. Shirmohammadi, H. Shahhosseini, et al., "Development and Evaluation of a Gamified Smartphone Mobile Health Application for Oral Health Promotion in Early Childhood: A Randomized Controlled Trial", BMC Oral Health, January 2021, 21 (1), 18.
24. W. Chang, P. Chang, Y. Chang, "The Gamification and Development of a Chatbot to Promote Oral Self-care by Adopting Behavior Change Wheel for Taiwanese Children", Digital Health, 2024, 10, 20552076241256750.
25. M. Pisano, A. Bramanti, F. Di Spirito, et al., "Reviewing Mobile Dental Apps for Children with Cognitive and Physical Impairments and Ideating an App Tailored to Special Healthcare Needs", Journal of Clinical Medicine, March 2025, 14 (6), 2105.
26. C. Baethge, S. Goldbeck-Wood, S. Mertens, "SANRA: A Scale for the Quality Assessment of Narrative Review Articles", Research Integrity and Peer Review, 2019, 4, 5.
27. R. Ferrari, "Writing Narrative Style Literature Reviews", Medical Writing, 2015, 24 (4), 230-235.
28. M. Page, J. McKenzie, P. Bossuyt, et al., "The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews", British Medical Journal, March 2021, 372, n71.
29. I. Blohm, J. Leimeister, "Gamification: Design of IT-based Enhancing Services for Motivational Support and Behavioral Change", Business and Information Systems Engineering, 2013, 5 (4), 275-278.
30. C. Abraham, S. Michie, "A Taxonomy of Behavior Change Techniques Used in Interventions", Health Psychology, 2008, 27 (3), 379-387.
31. S. Michie, S. Ashford, F. Sniehotta, et al., "A Refined Taxonomy of Behaviour Change Techniques to Help People Change Their Physical Activity and Healthy Eating Behaviours: The CALO-RE Taxonomy", Psychology and Health, November 2011, 26 (11), 1479-1498.
32. A. Bandura, "Health Promotion by Social Cognitive Means", Health Education and Behavior, 2004, 31 (2), 143-164.
33. I. Ajzen, "The Theory of Planned Behavior", Organizational Behavior and Human Decision Processes, 1991, 50 (2), 179-211.
34. J. Hamari, J. Koivisto, H. Sarsa, "Does Gamification Work? A Literature Review of Empirical Studies on Gamification", Proceedings of the 47th Hawaii International Conference on System Sciences, Institute of Electrical and Electronics Engineers, 2014, 3025-3034.
35. S. Michie, M. van Stralen, R. West, "The Behaviour Change Wheel: A New Method for Characterising and Designing Behaviour Change Interventions", Implementation Science, April 2011, 6, 42.
36. B. Tahani, S. Sadeghi Boldaji, H. Telleih, et al., "Development and Evaluation of the Effectiveness of a Gamified Oral Health Promotion App, Happy Teeth, in Schoolchildren: A Randomized Controlled Trial", BMC Oral Health, December 2025, 26 (1), 213.
37. K. Seaborn, D. Fels, "Gamification in Theory and Action: A Survey", International Journal of Human-Computer Studies, 2015, 74, 14-31.
38. T. Fleming, M. Poppelaars, H. Thabrew, "The Role of Gamification in Digital Mental Health", World Psychiatry, February 2023, 22 (1), 46-47.
39. M. Alkilzy, R. Midani, M. Hofer, et al., "Improving Toothbrushing with a Smartphone App: Results of a Randomized Controlled Trial", Caries Research, 2019, 53 (6), 628-635.
40. K. Parker, R. Bharmal, M. Sharif, "The Availability and Characteristics of Patient-focused Oral Hygiene Apps", British Dental Journal, April 2019, 226 (8), 600-604.

41. M. Sharif, A. Alkadhimi, "Patient Focused Oral Hygiene Apps: An Assessment of Quality and Knowledge Content", British Dental Journal, 2019, 227 (5), 383-386.
42. K. Hotwani, K. Sharma, D. Nagpal, et al., "Smartphones and Tooth Brushing: Content Analysis of the Current Available Mobile Health Apps for Motivation and Training", European Archives of Paediatric Dentistry, 2020, 21 (1), 103-108.
43. E. Meric, "Evaluation of the Quality of Oral Hygiene Mobile Apps for Children Using the Mobile App Rating Scale", International Journal of Medical Informatics, December 2024, 192, 105612.
44. S. Stoyanov, L. Hides, D. Kavanagh, et al., "Mobile App Rating Scale: A New Tool for Assessing the Quality of Health Mobile Apps", JMIR mHealth and uHealth, March 2015, 3 (1), e27.
45. S. Stoyanov, L. Hides, D. Kavanagh, et al., "Development and Validation of the User Version of the Mobile Application Rating Scale", JMIR mHealth and uHealth, 2016, 4 (2), e72.
46. B. Underwood, J. Birdsall, E. Kay, "The Use of a Mobile App to Motivate Evidence-based Oral Hygiene Behaviour", British Dental Journal, August 2015, 219 (4), E2.
47. E. Vayrynen, S. Hakola, A. Keski-Salmi, et al., "The Use of Patient-oriented Mobile Phone Apps in Oral Health: Scoping Review", JMIR mHealth and uHealth, September 2023, 11, e46143.
48. J. Scheerman, B. van Meijel, P. van Empelen, et al., "The Effect of Using a Mobile Application on Improving Oral Hygiene: A Randomized Controlled Trial", International Journal of Dental Hygiene, 2020, 18 (1), 73-83.
49. F. Zotti, D. Dalessandri, S. Salgarello, et al., "Usefulness of an App in Improving Oral Hygiene Compliance in Adolescent Orthodontic Patients", The Angle Orthodontist, 2016, 86 (1), 101-107.
50. D. Jacobson, J. Jacobson, T. Leong, et al., "Evaluating Child Toothbrushing Behavior Changes Associated with a Mobile Game App: A Single Arm Pre and Post Pilot Study", Pediatric Dentistry, July 2019, 41 (4), 299-303.
51. A. Aljafari, J. Gallagher, M. Hosey, "Can Oral Health Education Be Delivered to High-caries-risk Children and Their Parents Using a Computer Game? A Randomised Controlled Trial", International Journal of Paediatric Dentistry, 2017, 27 (6), 476-485.
52. A. Aljafari, R. ElKarmi, O. Nasser, et al., "A Video-game-based Oral Health Intervention in Primary Schools: A Randomised Controlled Trial", Dentistry Journal, May 2022, 10 (5), 90.
53. T. Mendonca, S. Carvalho, A. Aljafari, et al., "Oral Health Education for Children: Development of a Serious Game with a User-centered Design Approach", Games for Health Journal, August 2024, 13 (4), 268-277.
54. P. Reynolds, A. Donaldson, C. Liossi, et al., "How Families Prepare Their Children for Tooth Extraction under General Anaesthesia: Family and Clinical Predictors of Non-compliance with a Serious Game", International Journal of Paediatric Dentistry, 2019, 29 (2), 117-128.
55. S. Dey, S. Deshmukh, S. Umamaheshwari, et al., "Fluorescence-based Evaluation of the Efficacy of Augmented Reality-assisted Toothbrush on Oral Hygiene Practices among 6 to 8 Years Old Children", Journal of Advanced Oral Research, August 2023, 14 (2), 183-189.
56. S. Amantini, A. Montilha, B. Antonelli, et al., "Using Augmented Reality to Motivate Oral Hygiene Practice in Children: Protocol for the Development of a Serious Game", JMIR Research Protocols, January 2020, 9 (1), e10987.
57. H. Lin, Y. Lin, T. Wang, et al., "Effects of Incorporating Augmented Reality into a Board Game for High School Students’ Learning Motivation and Acceptance in Health Education", Sustainability, 2021, 13 (6), 3333.

58. Y. Kang, Y. Chang, S. Howell, "Using a Kinect-based Game to Teach Oral Hygiene in Four Elementary Students with Intellectual Disabilities", Journal of Applied Research in Intellectual Disabilities, March 2021, 34 (2), 606-614.
59. M. Karkoutly, M. Al-Halabi, M. Laflouf, et al., "Effectiveness of a Dental Simulation Game on Reducing Pain and Anxiety during Primary Molars Pulpotomy Compared with Tell-show-do Technique in Pediatric Patients: A Randomized Clinical Trial", BMC Oral Health, August 2024, 24 (1), 976.
60. Y. Kumar, S. Asokan, B. John, et al., "Effect of Conventional and Game-based Teaching on Oral Health Status of Children: A Randomized Controlled Trial", International Journal of Clinical Pediatric Dentistry, 2015, 8 (2), 123-126.
61. A. Malik, S. Sabharwal, A. Kumar, et al., "Implementation of Game-based Oral Health Education versus Conventional Oral Health Education on Children's Oral Health-related Knowledge and Oral Hygiene Status", International Journal of Clinical Pediatric Dentistry, 2017, 10 (3), 257-260.
62. U. Maheswari, S. Asokan, S. Asokan, et al., "Effects of Conventional versus Game-based Oral Health Education on Children's Oral Health-related Knowledge and Oral Hygiene Status: A Prospective Study", Oral Health and Preventive Dentistry, 2014, 12 (4), 331-336.
63. P. GeethaPriya, S. Asokan, D. Kandaswamy, et al., "Impact of Different Modes of School Dental Health Education on Oral Health-related Knowledge, Attitude and Practice Behaviour: An Interventional Study", European Archives of Paediatric Dentistry, 2020, 21 (3), 347-354.
64. Y. Shi, W. Wu, A. Huo, et al., "Effect of Conventional and Dental Truth or Dare Board Game on Oral Hygiene Knowledge and Oral Hygiene Status of Preschool Children", Games for Health Journal, April 2023, 12 (2), 125-131.
65. N. Sharififard, K. Sargeran, M. Gholami, et al., "A Music and Game-based Oral Health Education for Visually Impaired School Children: Multilevel Analysis of a Cluster Randomized Controlled Trial", BMC Oral Health, May 2020, 20 (1), 144.
66. P. Kashyap, L. Reddy, P. Sinha, et al., "Effectiveness of Game-based Oral Health Education Method on Oral Hygiene Performance of 12-year-old Private School Children in Lucknow City: A Field Trial", Journal of Indian Association of Public Health Dentistry, 2022, 20 (1), 43-48.
67. V. Santhosh, S. Shankkari, D. Coutinho, et al., "Effectiveness of a Toothbrushing Intervention Utilizing Puzzle-solving Game Assisted with Visual Aids among Adolescents: A Single-blind Randomized Controlled Trial", Przeglad Epidemiologiczny, December 2024, 78 (3), 318-325.
68. T. Saraf, R. Hegde, P. Shah, "Comparison of My Tooth the Happiest Educational Game with Standard Dietary Counseling for Preference toward Non-cariogenic Food Items in Preschool Children: A Randomized Control Trial", Journal of Indian Society of Pedodontics and Preventive Dentistry, 2023, 41 (1), 35-42.
69. S. Sharma, S. Saxena, S. Naik, et al., "Comparison between Conventional, Game-based, and Self-made Storybook-based Oral Health Education on Children's Oral Hygiene Status: A Prospective Cohort Study", International Journal of Clinical Pediatric Dentistry, 2021, 14 (2), 273-277.
70. S. Shirahmadi, S. Bashirian, A. Soltanian, et al., "Effectiveness of Theory-based Educational Interventions on Promoting Oral Health among Elementary School Students", BMC Public Health, January 2024, 24 (1), 130.
71. R. Mukhi, V. Shetty, V. Garcha, et al., "Comparative Evaluation of Effectiveness of Oral Health Education Methods on Oral Health Knowledge, Attitude and Status of 7 to 10 Year Olds: A

Randomized Controlled Trial", International Journal of Recent Scientific Research, 2018, 9, 26206-26210.
72. M. Shirmohammadi, S. Razeghi, A. Shamshiri, et al., "Impact of Smartphone Application Usage by Mothers in Improving Oral Health and Its Determinants in Early Childhood: A Randomised Controlled Trial in a Paediatric Dental Setting", European Archives of Paediatric Dentistry, August 2022, 23 (4), 629-639.
73. L. Krishnan, K. Iyer, P. Madan Kumar, "Effectiveness of Two Sensory-based Health Education Methods on Oral Hygiene of Adolescents with Autism Spectrum Disorders: An Interventional Study", Special Care in Dentistry, 2021, 41 (5), 626-633.
74. S. Lopez Cazaux, G. Lefer, A. Rouches, et al., "Toothbrushing Training Programme Using an iPad for Children and Adolescents with Autism", European Archives of Paediatric Dentistry, 2019, 20 (3), 277-284.
75. A. Narzisi, M. Bondioli, F. Pardossi, et al., "Mom Let Us Go to the Dentist: Preliminary Feasibility of a Tailored Dental Intervention for Children with Autism Spectrum Disorder in the Italian Public Health Service", Brain Sciences, July 2020, 10 (7), 444.
76. K. France, O. Urquhart, E. Ko, et al., "A Pilot Study Exploring Caregivers' Experiences Related to the Use of a Smart Toothbrush by Children with Autism Spectrum Disorder", Children, April 2024, 11 (4), 460.
77. B. Tan, R. Nair, M. Duggal, et al., "Development of Oral Health Resources and a Mobile App for Caregivers and Autistic Children through Consensus Building", Autism, 2024, 28 (4), 959-974.
78. E. Mahmoudi, P. Yoo, A. Chandra, et al., "Gamification in Mobile Apps for Children with Disabilities: Scoping Review", JMIR Serious Games, September 2024, 12, e49029.
79. B. Borrelli, R. Endrighi, T. Heeren, et al., "Parent-targeted Oral Health Text Messaging for Underserved Children Attending Pediatric Clinics: A Randomized Clinical Trial", JAMA Network Open, January 2025, 8 (1), e2452780.
80. K. Ajay, L. Azevedo, A. Haste, et al., "App-based Oral Health Promotion Interventions on Modifiable Risk Factors Associated with Early Childhood Caries: A Systematic Review", Frontiers in Oral Health, March 2023, 4, 1125070.
81. N. Mohammadzadeh, M. Gholamzadeh, S. Zahednamazi, et al., "Mobile Health Applications for Children's Oral Health Improvement: A Systematic Review", Informatics in Medicine Unlocked, 2023, 37, 101189.
82. F. Peerbhay, R. Mash, S. Khan, "Effectiveness of Oral Health Promotion in Children and Adolescents through Behaviour Change Interventions: A Scoping Review", PLOS ONE, 2025, 20 (1), e0316702.
83. J. Wainwright, A. Sheiham, "An Analysis of Methods of Toothbrushing Recommended by Dental Associations, Toothpaste and Toothbrush Companies and in Dental Texts", British Dental Journal, August 2014, 217 (3), E5.
84. T. Walsh, H. Worthington, A. Glenny, et al., "Fluoride Toothpastes of Different Concentrations for Preventing Dental Caries", Cochrane Database of Systematic Reviews, March 2019, 3, CD007868.
85. V. Padmanabhan, S. D'Souza, S. Priya, et al., "Harnessing the Potential of Oral Hygiene Apps for Pediatric Dental Care: A Comprehensive Narrative Review", Journal of International Dental and Medical Research, 2024, 17 (2), 860-865.

86. American Academy of Pediatric Dentistry, "Behavior Guidance for the Pediatric Dental Patient", The Reference Manual of Pediatric Dentistry, American Academy of Pediatric Dentistry, Chicago, 2023, 359-377.
87. M. Pisano, A. Bramanti, D. Menditti, et al., "Modern Approaches to Providing Telematics Oral Health Services in Pediatric Dentistry: A Narrative Review", Applied Sciences, 2023, 13 (14), 8331.