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Review Article

Effects of Digital Health Interventions on Oral Hygiene and Treatment Compliance in Orthodontic Patients: A Systematic Review

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ABSTRACT

BACKGROUND: Oral hygiene and treatment compliance are critical for successful orthodontic outcomes. Despite their importance, patient non-adherence remains a significant challenge, contributing to complications such as plaque accumulation, gingivitis, and delayed treatments. Digital health interventions, including mobile apps, telemonitoring, and gamified platforms, offer innovative approaches to address these issues.

OBJECTIVE: This systematic review evaluates the effectiveness of digital health interventions in improving oral hygiene and treatment compliance among orthodontic patients, compared to traditional methods.

METHODS: A comprehensive search was conducted across databases including MEDLINE, Cochrane Library, EMBASE, and Scopus. Peer-reviewed randomized controlled trials (RCTs) and controlled clinical trials (CCTs) assessing digital health tools in orthodontics were included. Data were extracted and analyzed descriptively, focusing on outcomes such as Plaque Index (PI), Gingival Index (GI), compliance rates, and patient engagement.

RESULTS: Seven studies involving 504 participants aged 10–36 years were included. Digital tools demonstrated consistent improvements in oral hygiene, with significant reductions in PI and GI. Gamified apps, motivational protocols via social platforms, and telemonitoring enhanced compliance and reduced white spot lesions. However, short study durations and variability in interventions limited long-term effectiveness assessments.

CONCLUSION: Digital health interventions show promise in enhancing orthodontic care by improving oral hygiene and compliance. Further research with standardized methodologies, long-term follow-up, and cost-effectiveness analyses is needed to validate their integration into routine practice.

KEYWORDS: Orthodontics, Digital health interventions, Oral hygiene, Patient compliance, Mobile health (mHealth), Telemonitoring, Gamification.

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INTRODUCTION

Oral hygiene and treatment compliance are cornerstone factors in the success of orthodontic therapy.[1] Orthodontic treatment inherently requires long-term patient adherence to specific behavioural guidelines, including proper oral hygiene practices, dietary restrictions, and regular follow-up visits.[2] Despite the critical role of compliance, non-adherence remains a persistent challenge, leading to complications such as increased plaque accumulation, gingivitis, white spot lesions, and delayed treatment outcomes.[3] The rise of digital health interventions offers promising solutions to address these challenges by providing innovative tools for patient education, monitoring, and engagement.

Digital health interventions encompass a wide range of technologies, including mobile health applications (mHealth), wearable devices, telehealth platforms, and artificial intelligence-based solutions. [4,5] These interventions aim to bridge gaps in healthcare delivery, enhance patient engagement, and improve health outcomes. In orthodontics, digital technologies have found applications in areas such as virtual consultations, treatment progress tracking, and real-time feedback on oral hygiene practices. [6,7] However, the specific impact of these interventions on treatment compliance and oral hygiene among orthodontic patients warrants systematic evaluation.

Traditional methods for encouraging compliance in orthodontic care have primarily relied on direct patient-provider interactions, verbal counselling, and printed educational materials. While these approaches are effective to some extent, they often fail to engage patients consistently and may not cater to individual needs. Moreover, the modern patient population increasingly prefers digital and interactive solutions that align with their daily routines and technological habits. [8,9] Digital health interventions, by leveraging mobile applications and online platforms, offer personalized and interactive strategies to foster behavioural change. For instance, gamification elements, reminders, and educational videos have demonstrated potential in enhancing patient adherence to prescribed oral hygiene practices.[10]

Orthodontic patients, particularly adolescents, are highly receptive to technology-based solutions. Studies suggest that digital tools can not only improve their understanding of orthodontic care but also create a sense of accountability. Mobile applications, for instance, provide reminders for brushing and flossing, while wearable sensors can track patient compliance with appliance wear.[11-12] Telehealth platforms facilitate virtual consultations, reducing barriers to access and allowing timely professional guidance. Despite these advancements, the effectiveness of digital health interventions in improving long-term compliance and oral hygiene outcomes in orthodontic patients remains underexplored in a systematic manner.[13]

Several factors influence the impact of digital health interventions, including their design, content quality, user interface, and integration with routine orthodontic care. Additionally, patient demographics, socioeconomic status, and baseline technological literacy play pivotal roles in determining the success of these interventions. [14,15] While some studies highlight the benefits of digital tools in orthodontic care, others point to challenges such as patient disengagement over time, privacy concerns, and the lack of robust evidence on long-term outcomes. A systematic review of the available literature is therefore essential to provide clarity on the effectiveness and limitations of these interventions.

The COVID-19 pandemic acted as a catalyst for the increased adoption of digital health technologies across various medical and dental disciplines. Social distancing measures and restrictions on in-person consultations necessitated the use of telehealth platforms and remote monitoring tools in orthodontics. This paradigm shift underscored the potential of digital health interventions to ensure continuity of care and foster patient engagement during unprecedented circumstances. However, this rapid transition also exposed gaps in technological infrastructure, accessibility, and provider training, which may influence the effectiveness of these interventions.[16-17]

This review is novel in its comprehensive approach to synthesizing evidence on how digital health interventions specifically affect oral hygiene and treatment compliance in orthodontic patients. Unlike previous studies that focus on broader aspects of digital health or general dental care, this review narrows its scope to orthodontics, highlighting the unique challenges and opportunities in this field. Furthermore, it aims to provide an in-depth analysis of emerging digital tools and their potential for integration into routine orthodontic practice.

The primary aim of this systematic review is to evaluate the impact of digital health interventions on oral hygiene and treatment compliance in orthodontic patients. Specifically, it seeks to assess the effectiveness of various digital tools, identify factors influencing their success, and explore challenges associated with their implementation. By addressing these objectives, this review aspires to bridge the existing knowledge gap, offering valuable insights for practitioners, researchers, and policymakers seeking to leverage digital technologies to enhance orthodontic outcomes.

MATERIALS AND METHODS

This systematic review adhered to the guidelines outlined in the Cochrane Handbook for Systematic Reviews of Interventions and followed PRISMA guidelines to ensure methodological rigor and transparency. The review protocol was registered in PROSPERO with ID CRD42024622625.

Focused Question

Are digital health interventions successful in enhancing oral hygiene and treatment compliance among orthodontic patients compared to traditional methods?

Search Strategy

A systematic electronic database search was performed, encompassing MEDLINE/PubMed, EMBASE, Cochrane Library, Scopus, Web of Science, and Google Scholar. The search strategy combined Medical Subject Headings (MeSH) terms and free-text keywords related to orthodontic patients, digital health interventions, and oral hygiene compliance, such as “orthodontic patients,” “digital health interventions,” “mobile applications,” “tele dentistry,” “plaque index,” and “treatment compliance.” Boolean operators (AND, OR) were used to refine results, ensuring coverage of studies involving orthodontic patients using digital health tools to improve oral hygiene or treatment adherence. References from included articles and systematic reviews were manually screened for additional relevant studies. The study selection, following PRISMA guidelines, involved detailed full-text reviews of all identified studies, with decisions based on predefined inclusion criteria. Additionally, a manual review of the included studies was performed to ensure comprehensive coverage of the available literature. A detailed summary of the study selection process has been presented using the PRISMA 2020 flow Diagram [Figure 1].

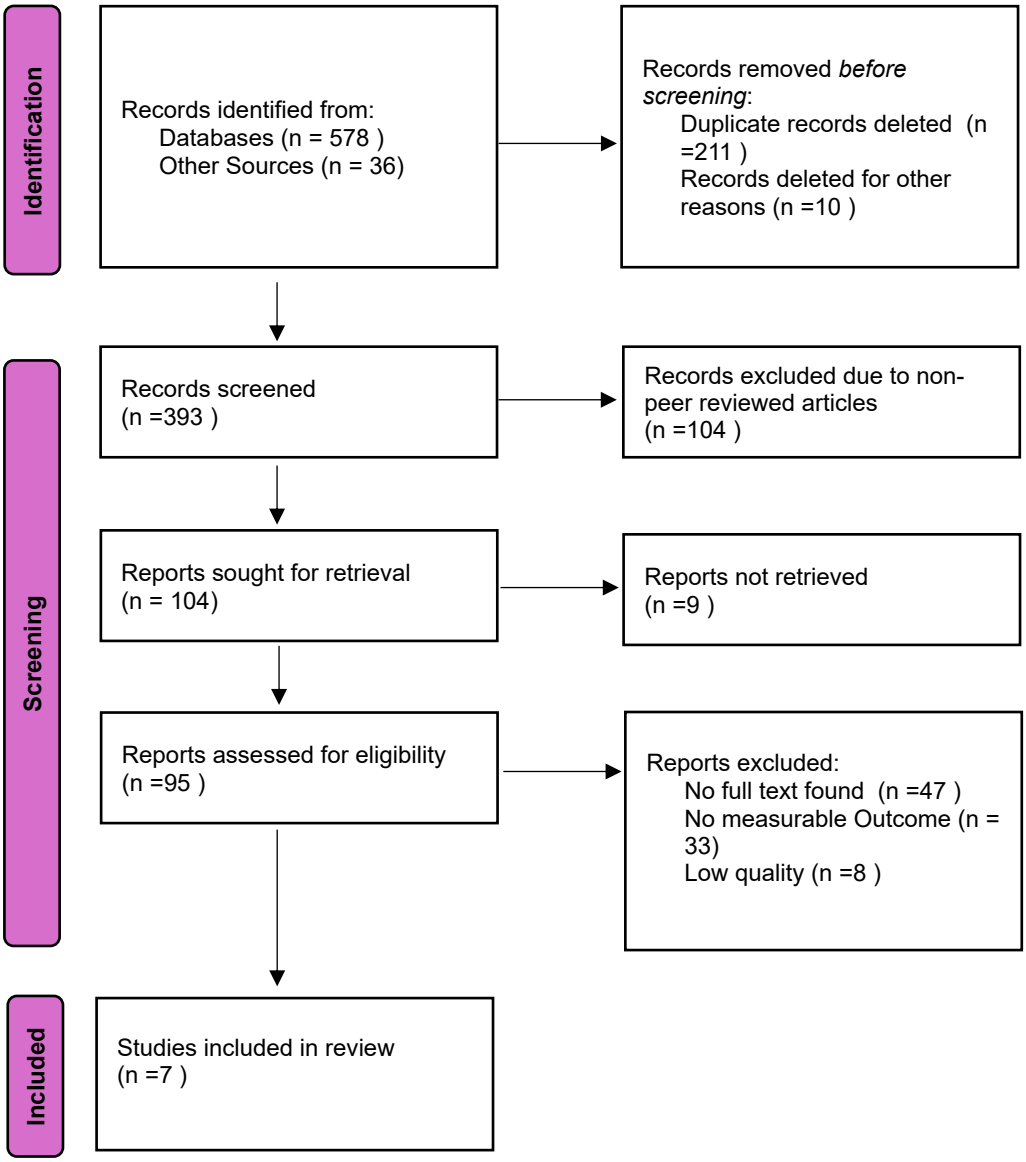

Figure-1 PRISMA flow diagram

Inclusion Criteria

- Peer-reviewed randomized controlled trials (RCTs).
- Studies including orthodontic patients of any age and gender.
- Studies evaluating digital health interventions (e.g., mobile apps, telemonitoring, or gamified platforms) for oral hygiene and treatment compliance.
- Outcome measures including oral hygiene indices, patient compliance rates, and patient-reported outcomes.

Exclusion Criteria

- Non-peer-reviewed articles, conference abstracts, reviews, and case reports.

- Studies involving non-orthodontic populations or interventions unrelated to digital health.
- Studies lacking measurable outcomes on oral hygiene or compliance.
- Unpublished studies or those with incomplete data.

The PICOS framework (Participants, Interventions, Comparisons, Outcomes, and Study design) directed the establishment of the inclusion and exclusion criteria. [Table 1].

Table-1 PICOS Criteria

Parameter	Description
Population	Orthodontic patients of any age and gender undergoing treatment requiring oral hygiene management and compliance monitoring.
Intervention	Digital health interventions such as mobile applications, tele orthodontics, gamification tools, and other digital platforms aimed at improving oral hygiene and treatment compliance.
Comparison	Conventional methods (e.g., in-person instructions, traditional educational tools, or no intervention).
Outcomes	Oral hygiene indices (e.g., Plaque Index, Gingival Index), compliance rates, patient-reported satisfaction, and adherence to treatment protocols.
Study Design	Randomized controlled trials (RCTs) and controlled clinical trials (CCTs).

Study Selection and Screening

The study selection process was carried out in four distinct stages. Initially, irrelevant titles and abstracts were excluded based on their lack of relevance to the research topic. Next, the remaining articles were screened against the predefined inclusion and exclusion criteria by two independent reviewers to ensure alignment with the study's objectives. This was followed by a thorough full-text evaluation of the eligible articles to confirm their suitability for inclusion. Finally, data extraction and critical appraisal of the selected studies were performed to assess their quality and relevance. Any discrepancies that arose during the screening process were resolved through consensus or, when necessary, by consulting a third reviewer.

Data Extraction

Data were extracted using a standardized form to ensure consistency and accuracy. The extracted information included details about the study design and sample size, participant demographics such as age, gender, and stage of orthodontic treatment, and the type and duration of the digital health intervention. Additionally, comparator interventions, where applicable, were documented, along with the primary and secondary outcomes, which included oral hygiene indices, compliance scores, and patient satisfaction. A comprehensive summary of the extracted data is presented in Table 2 for clarity and reference.

Table-2 The characteristics of the studies selected for this systematic review.

Study Name	Study Design & Sample Size	Participant Demographics	Type & Duration of Digital Health Intervention	Comparator Intervention	Primary & Secondary Outcomes
Delouse et al	Multicentre RCT, n = 38	Adolescents (12–18 years), Mean age: 13.9 ± 1.2, 39.5% female, 60.5% male	Interactive oscillating/rotating toothbrush + smartphone app (18 weeks)	Non-interactive oscillating toothbrush	**Primary**: Plaque Index (PI) **Secondary**: Gingival Index (GI), White Spot Lesion (WSL) scores
Sangalli et al	Prospective study, n = 30	Adolescents and adults (10–36 years), Mean age: 20.6 ± 9.0, 50% male, 50% female	Dental Monitoring® app + monthly remote photo monitoring (6 months)	Standard care	**Primary**: PI, GI, WSL **Secondary**: Carious Lesion Onset (CLO), Emergency Appointments (EA)
Alkadhi et al	Single-blinded RCT, n = 44	Adolescents (≥12 years), Equal gender distribution in Group I	Mobile app providing reminders (3x/day) + video instructions (4 weeks)	Verbal oral hygiene instructions	**Primary**: PI, GI
Soltan mohamadi Borujeni et al	RCT, n = 60	Adolescents (12–18 years) and adults (>18 years), Equal gender	5-minute educational video via Telegram app (3 follow-up visits)	In-person education with a dental model	**Primary**: PI, Bleeding on Probing (BOP) **Secondary**: Gingival colour and consistency
Farhadifard et al	RCT, n = 120	Adolescents and young adults (15–25 years), Mean age: 18.7 ± 3.87, 84.2% female	Brush DJ app with 2-min music timer + brushing reminders (12 weeks)	Verbal instructions, brochures, and videos	**Primary**: PI, GI **Secondary**: Brushing frequency, brushing duration, app usage frequency
Scheerman et al	RCT, n = 132	Adolescents (12–16 years), Mean age: 13.2–13.5, 61.2% female, 38.8% male	"WhiteTeeth" app for coaching + self-monitoring (12 weeks)	Routine care and verbal instructions	**Primary**: PI, Gingival Bleeding Sites **Secondary**: Oral health behaviours, psychosocial factors (e.g., risk perception, self-efficacy)
Zotti et al	RCT, n = 80	Adolescents (~13.6 years CG, ~14.1 years SG), Equal gender distribution	WhatsApp-based motivational protocol with weekly photo submissions (1 year)	Traditional hygiene instructions	**Primary**: PI, GI **Secondary**: Reduction in White Spot Lesions (WSLs), caries development

Included Studies in this systematic review provide a comprehensive overview of the diverse digital health interventions used to improve oral hygiene and treatment compliance in orthodontic patients. These interventions ranged from mobile apps and educational videos to interactive tools such as oscillating toothbrushes with smartphone integration. The sample sizes, study designs, and participant demographics varied, reflecting the applicability of digital tools across different populations and age groups.

Most studies focused on primary outcomes such as plaque index (PI) and gingival index (GI), which are critical indicators of oral hygiene. Secondary outcomes included patient engagement metrics such as brushing frequency and duration, the incidence of white spot lesions (WSLs), carious lesion onset (CLO), and psychosocial factors like self-efficacy and risk perception. The findings collectively underscore the potential of digital tools to complement traditional oral hygiene education by offering personalized, accessible, and engaging solutions.

However, it is important to note variations in the duration and design of the interventions. While some studies involved short-term trials (e.g., 4–12 weeks), others extended their scope to one year, providing a better understanding of long-term compliance and outcomes.

Risk of Bias Assessment

The Cochrane Risk of Bias 2.0 (ROB 2) tool was used to assess the quality of included randomized controlled trials (RCTs), evaluating sequence generation, blinding of participants and personnel, allocation concealment, incomplete outcome data, and selective reporting. For the non-randomized study, the Risk of Bias in Non-Randomized Studies of Interventions (ROBINS-I) tool was applied to assess potential biases across key domains. (Tables-3,4).

Data Analysis

A descriptive synthesis of the findings was performed due to the heterogeneity of study designs, intervention types, and outcome measures. The results were organized and presented under key themes, including the effectiveness of digital health interventions in improving oral hygiene and enhancing treatment compliance. Trends and patterns were analyzed qualitatively, highlighting similarities and differences across the included studies. The findings were further contextualized with existing literature to provide insights into the potential of digital health tools in orthodontic care.

A meta-analysis was not conducted due to significant heterogeneity in study designs, intervention types, outcome measures, and follow-up durations. The included studies utilized different digital health interventions, assessed a variety of clinical and behavioural outcomes, and had varying methodologies. Therefore, a descriptive synthesis was performed, categorizing findings based on key themes to provide a comprehensive understanding of the impact of digital interventions on oral hygiene and treatment compliance

RESULTS

Search and Selection

This systematic review included seven studies involving 504 participants aged between 10 and 36 years. The studies evaluated the effects of various digital health interventions on oral hygiene and treatment compliance in orthodontic patients. All studies compared digital tools, such as mobile applications, interactive devices, and

remote monitoring systems, with traditional oral hygiene instructions or standard care. A PRISMA flow diagram illustrates the selection process.

Effect on Oral Hygiene (Plaque and Gingival Index)

Across all studies, digital health interventions demonstrated a consistent improvement in oral hygiene outcomes.

- Delouse et al. [18] reported significantly reduced PI and GI scores among participants using an interactive oscillating toothbrush paired with a smartphone app compared to non-interactive toothbrush users.
- Zotti et al. [24] and Sangalli et al. [19] observed similar trends, with reductions in PI and GI when motivational protocols via WhatsApp or the Dental Monitoring® app were implemented.
- Farhadifard et al. [22] found the Brush DJ app improved brushing frequency and reduced plaque levels, with patients reporting higher compliance and satisfaction.

Reduction in White Spot Lesions (WSLs)

Five studies highlighted the impact of digital tools on WSL reduction. Sangalli et al. [19] reported significant improvements in WSL scores among patients using the Dental Monitoring® app with remote photo monitoring. Zotti et al. [24] noted a marked reduction in WSLs in participants receiving weekly motivational reminders and photo submissions through WhatsApp compared to traditional hygiene instructions.

Treatment Compliance and Patient Engagement

Digital health interventions promoted better compliance and engagement among patients. For instance, Farhadifard et al. [22] demonstrated that daily reminders via the Brush DJ app significantly increased brushing frequency and duration. Scheerman et al.[23] noted that the “WhiteTeeth” app improved self-monitoring behaviours, psychosocial factors, and adherence to prescribed oral hygiene regimens.

Risk of Bias

All randomized controlled trials (RCTs) demonstrated a low risk of bias in random sequence generation, allocation concealment, and selective reporting. However, high risks were noted in the blinding of participants and personnel across all RCTs due to the nature of the interventions. The study by Scheerman et al. also exhibited a high risk in the blinding of outcome assessment. Despite these limitations, all included RCTs were deemed to have a moderate overall risk of bias, suggesting reliable, albeit not conclusive, findings.

For the non-randomized study by Sangalli et al. [19], ROBINS-I tool was used, which indicated a moderate overall risk of bias due to potential confounding, deviations from intended interventions, and measurement bias. While this study provides valuable insights, its non-randomized design necessitates cautious interpretation of findings. [Tables-3,4].

TABLE-3 Risk of Bias Assessment of Included RCTs through Cochrane ROB 2.0 tool

Study Name	Random Sequence Generation	Allocation Concealment	Blinding of Participants and Personnel	Blinding of Outcome Assessment	Incomplete Outcome Data	Selective Reporting	Other Bias	Overall Risk of Bias
Delouse et al.	Low	Low	High	Low	Low	Low	Low	Moderate
Alkadhi et al.	Low	Low	High	Low	Low	Low	Low	Moderate
Soltanmohamadi et al.	Low	Low	High	Low	Low	Low	Low	Moderate
Farhadifard et al.	Low	Low	High	Low	Low	Low	Low	Moderate
Scheerman et al.	Low	Low	High	High	Low	Low	Low	Moderate
Zotti et al.	Low	Low	High	Low	Low	Low	Low	Moderate

TABLE-4 Risk of Bias Assessment of Included non RCTs through ROBINS-1 tool

Bias Domain	Confounding	Selection Bias	Classification of Interventions	Deviations from Intended Interventions	Missing Data	Measurement of Outcomes	Selection of Reported Results	Overall Risk of Bias
Risk Assessment	Moderate	Low	Low	Moderate	Low	Moderate	Moderate	Moderate

DISCUSSION

Impact of Digital Health Interventions on Oral Hygiene

This systematic review underscores the effectiveness of digital health interventions in improving oral hygiene outcomes among orthodontic patients. Across multiple studies, significant reductions in plaque index (PI) and gingival index (GI) scores were observed, highlighting the utility of tools such as Brush DJ and Dental Monitoring® in promoting better oral hygiene practices. The use of motivational protocols via social messaging platforms, such as WhatsApp, further demonstrated the potential of digital tools to reduce plaque and gingival inflammation through engaging and consistent patient interaction.

Reduction in White Spot Lesions (WSLs)

White spot lesions (WSLs), a common adverse effect of orthodontic treatment, were significantly reduced in studies employing digital interventions. Tools offering remote photo monitoring and motivational feedback helped prevent WSL development by promoting adherence to oral hygiene protocols. These findings suggest that timely feedback and continuous monitoring are critical components in addressing complications associated with orthodontic care.

Influence on Patient Compliance and Psychosocial Factors

Digital health interventions were particularly effective in improving patient compliance and addressing behavioural barriers to oral hygiene. Self-monitoring apps, such as “WhiteTeeth,” enhanced psychosocial factors, including risk perception, self-efficacy, and motivation, which in turn improved adherence to oral hygiene routines. Interventions that combined educational and motivational components fostered a sense of accountability and engagement, ensuring better long-term compliance.

Long-Term Effectiveness, Implementation Challenges, and Patient Satisfaction

While digital health interventions improve oral hygiene and compliance, their long-term effectiveness remains uncertain due to limited follow-up periods. Sustained engagement may decline over time due to loss of motivation and lack of reinforcement. Future research should explore whether periodic reminders or provider-led reinforcement can help maintain adherence. Additionally, psychosocial factors such as self-efficacy, motivation, and technological literacy influence intervention success, highlighting the need for more tailored approaches. Kitsaras G et al [25] assessed the efficacy of the "Know Your OQ™" digital oral health intervention across two studies involving 296 US adults, revealing significant improvements in participants' oral health knowledge and attitudes following intervention completion. While changes in self-reported practices were more pronounced in the second study, both demonstrated a positive trend, coupled with high comprehensibility and favourable participant feedback, suggesting the intervention's potential as a valuable tool for enhancing oral health awareness and promoting positive behavioural shifts within a diverse population. A study [26] in a semi-government teaching hospital found that while patients showed awareness of oral hygiene practices, their actual behaviour demonstrated a lack of adherence. Patients were more concerned about dental caries resulting from poor oral hygiene than its impact on treatment outcomes.

Implementation challenges also impact real-world adoption. Issues such as integration into clinical workflows, digital literacy, and smartphone access may limit accessibility. Furthermore, patient satisfaction plays a key role—while personalized feedback and gamification improved engagement, some patients found frequent notifications intrusive. Future research should focus on identifying scalable, user-friendly, and cost-effective digital health strategies that balance engagement with practicality.

Integration of AI in Digital Health Interventions

The potential of artificial intelligence (AI) in healthcare aligns with the increasing use of digital technologies in orthodontics, offering new possibilities for enhancing patient education and clinical decision-making. [25] Advances in automatic tooth segmentation in digital dental models have improved, but the precise identification of orthodontic treatment needs, particularly for borderline cases, remains a significant hurdle.. AI can help diagnose orthodontic findings and detect contraindications, such as active dental caries, apical lesions or periodontitis. [26] AI-driven platforms, such as automated image analysis for oral hygiene assessment, personalized patient reminders, and adaptive treatment recommendations, could further improve compliance and treatment outcomes. [25, 27] Machine learning algorithms may help predict patient adherence patterns, allowing orthodontists to implement proactive interventions. Additionally, AI-powered chatbots and virtual assistants could provide real-time patient support, addressing common concerns and reinforcing oral hygiene practices.[28,29] Future research should explore how integrating AI with existing digital interventions can optimize engagement, improve long-term adherence, and enhance overall orthodontic care.

Limitations of the Included Studies

Despite the promising outcomes observed in this review , a number of limitations were identified across the Analyzed studies. One major limitation was the short follow-up durations, with most studies spanning only 4 to 12 weeks. This restricted the evaluation of long-term effectiveness, particularly in assessing sustained improvements in oral hygiene and treatment compliance. Additionally, significant heterogeneity in study designs, including variability in intervention types, sample sizes, and comparator methods, complicated direct comparisons and limited the generalizability of findings. Another concern was the moderate risk of bias observed in all studies, particularly in the blinding of participants and personnel, which was inherently challenging due to the nature of digital interventions. Some studies also exhibited bias in outcome assessments, further affecting the reliability of results. Furthermore, confounding variables, such as baseline oral hygiene practices, socioeconomic factors, and patient demographics, were not consistently controlled, potentially influencing the observed outcomes and limiting the accuracy of conclusions drawn from the data.

Recommendations for Future Research

To overcome these limitations and build a more robust evidence base, future research should focus on several key areas. First, standardized methodologies should be employed, including consistent intervention protocols, outcome measures, and comparator methods, to facilitate robust comparisons and meta-analyses. Second, long-term studies with extended follow-up periods are essential to assess the sustainability of improvements in oral hygiene and compliance, as well as the prevention of complications such as white spot lesions (WSLs) and caries. Third, the cost-effectiveness of digital health interventions should be evaluated to determine their feasibility and scalability in routine orthodontic practice. Fourth, future studies should include comprehensive assessments,

integrating clinical outcomes with patient-reported measures such as satisfaction, ease of use, and perceived benefits, to provide a holistic understanding of these interventions' impact. Lastly, researchers should explore the integration of digital tools into diverse clinical settings, addressing potential barriers such as technology access, literacy, and cultural differences to ensure their broad applicability and acceptance. By addressing these areas, future studies can provide more conclusive evidence and pave the way for the effective implementation of digital health interventions in orthodontic care.

Clinical Implications

Digital health interventions offer a valuable adjunct to traditional orthodontic care, delivering personalized, scalable, and engaging solutions to improve oral hygiene and compliance. By fostering behavioural change and providing real-time feedback, these tools empower patients to take greater ownership of their oral health. However, successful integration into clinical workflows requires consideration of patient-specific factors, including age, technology access, and individual preferences.

CONCLUSION

Digital health interventions represent a promising advancement in orthodontic care, demonstrating significant benefits in improving oral hygiene, reducing WSLs, and enhancing treatment compliance. While these findings are encouraging, further research with long-term trials, standardized methodologies, and a focus on cost-effectiveness is essential to validate their utility and explore their broader application. With advancements in technology and increasing emphasis on patient-cantered care, digital interventions are poised to become integral components of orthodontic practice, ultimately improving patient outcomes and satisfaction.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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