E-ISSN 2250-0944
ISSN 2250-1150
doi: 10.31838/ijprt/16.02.882

Research Article

Artificial Intelligence-Based Oral Hygiene Application with Scaling and Root Planing in Adult Periodontitis Patients

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Received: 02.09.26, Revised: 06.10.26, Accepted: 12.11.26

ABSTRACT

The irreversible damage is caused by inflammatory aggression and biofilm accumulation. Periodontal treatment is directed towards the elimination of the cause of inflammation and biofilm control, along with the maintenance of adequate oral hygiene. Recently, it has been shown that AI-based applications could promote oral hygiene practices and patient compliance. The aim of the study was to assess the efficacy of an AI-based oral hygiene application in the framework of scaling and root planing in the adult population with periodontitis. A randomized controlled clinical trial was performed with 120 participants of 25 to 55 years of age, diagnosed with periodontitis. Participants were evenly distributed in two groups. Group I was submitted to scaling and root planing along with routine oral hygiene instructions. Group II was submitted to the same treatment as Group I and in addition was instructed to use the AI-based oral hygiene application (Dentulu) to guide and provide reminders on oral hygiene. The clinical parameters evaluated were PI, GI, PD and CAL. The clinical evaluation was performed prior to the intervention and after three months. Clinical improvement was observed in Group II when compared to Group I. The PI of Group II reduced from 1.82 ± 0.42 to 0.72 ± 0.25 and Group I reduced from 1.79 ± 0.39 to 1.05 ± 0.31. Significant improvements were also observed in GI, PD and CAL of Group II compared to Group I. Patient compliance was higher in the AI-assisted group (88.3% vs. 65.0%). The study suggested that using an AI-based oral hygiene application along with scaling and root planing enhanced periodontal health parameters and patient compliance as compared to conventional periodontal therapy.

Keywords: Artificial Intelligence, Oral Hygiene, Root Planing, Periodontitis.

INTRODUCTION

Periodontitis is a chronic inflammatory disease of the supporting tissues of the teeth caused and influenced by dysbiotic biofilm and results in the irreversible destruction of the periodontal ligament and underlying bone. Periodontitis can lead to tooth loss and has detrimental effects on a person's quality of life, especially if it is not treated. The long term nature of the treatment required for periodontitis and the increased prevalence of the disease makes periodontitis a significant public health issue (1).

Severe periodontitis is a major clinical and public health challenge, particularly among middle-aged and older adults. It was estimated that over 1 billion people, primarily in South Asia, suffered from the disease in 2021. Treatment for severe periodontitis requires not only professional care, but participation by the patient in daily oral hygiene practices. Effective management and control of periodontitis requires participation and collaboration by the patient and professional dental care team over a prolonged period of time (2).

Dental health education delivered through mobile applications is a promising method for enhancing oral hygiene practices. Lee, Choi, and Jung evaluated a mobile application based dental health education and found improvements in oral health knowledge and some oral health practices in the participants (3).

It was stated that digital education probably strengthens oral hygiene practices. This was inferred from the results of the study, despite the fact that the study did not restrict the participants to only include patients with periodontitis. More studies are needed to assess the potential role of digital education and other modes of education for individuals undergoing periodontal therapy (4).

Scaling and root planing (SRP) is the mainstay of non-surgical periodontal therapy. The objective of SRP is to remove oral biofilm and calcified deposits from tooth and root surfaces. This procedure helps to reduce local inflammatory factors and supports periodontal healing. The efficacy of SRP is evaluated based on reduction in clinical signs of periodontal disease such as reduction in calculus, plaque and clinical attachment level (CAL) and pocket depth. Improvement following SRP largely depends on the patient's willingness and ability to control oral biofilm accumulation and maintain periodontal health (Adherence to periodontal therapy). Adherence to periodontal therapy is challenging because oral hygiene measures should be practiced regularly to achieve the desired outcome. Oral hygiene measures should be practiced not only when the patient is in the dental office, but also at home. Several digital health (DH) solutions have been developed to address the periodontal adherence challenge. These solutions rely on behavior change theories and design thinking to promote self-care practices and improve adherence to clinical recommendations through behavioral nudges, educational content, and behavioral and emotional support. Other recently developed technologies, such as those based on artificial intelligence, may help interpret and evaluate clinical periodontal parameters as well as provide periodontal health care education in individualized and innovative ways (5).

Nevertheless, the utility of AI is limited by the accuracy of its evaluations, the kind and quality of feedback it gives, patient engagement, as well as the integration of digital suggestions and professional clinical judgment (6).

There is a growing body of evidence, including the use of AI to monitor patients undergoing periodontal treatment. Shen and Huang assessed the use of an AI-based dental monitoring application in patients undergoing nonsurgical periodontal therapy to evaluate the effectiveness of remote monitoring to improve treatment outcomes. This study illustrated the growing interest to utilize smartphone applications in periodontal therapy. Although digital interaction may facilitate communication, strengthen understanding, and reinforce oral hygiene, more research is needed to substantiate these benefits through improved clinical outcomes (7).

From the same body of evidence, are randomized controlled clinical studies that employed AI-enabled toothbrush technology and mobile health messages. Li and colleagues studied an AI-enabled multimodal-sensing toothbrush integrated with mobile health technology in the care of periodontal patients to improve oral hygiene. Another randomized controlled trial assessed the use of motivation, education, and application-supported periodontal treatment to evaluate clinical, cognitive, and psychomotor outcomes. The study employed AI to support periodontal care and oral hygiene (8).

Additional research on oral hygiene apps has focused on plaque scores, bleeding on probing, probing pocket depths and subgingival microbiology. These studies establish the foundation for digital periodontal support and illustrate the need for distinguishing the effect of traditional mobile applications from that of AI applications (9).

However, the available evidence does not suggest that every digital intervention offers additional clinical benefits over traditional oral hygiene instructions. One randomized controlled clinical trial investigated the use of a mobile application for oral hygiene instructions and found improvement in the periodontal parameters of both study groups. However, statistically significant differences were not observed between the groups for the primary endpoints. Likewise, mobile health interventions focused on reminders have shown potential to enhance the practice of interdental cleaning. The impact of these interventions, however, remains dependent on the design of the intervention and level of participation of the patients. Further controlled research is needed to clarify the benefits of an AI-based oral hygiene application integrated with SRP (10).

This study aimed to assess the benefits of using an AI-based oral hygiene application in combination with scaling and root planing in adult patients with periodontitis. The study compared the effects of conventional SRP with routine oral hygiene instructions with SRP integrated with an AI-based application to provide users personalized brushing feedback, education and reminders. Changes in Plaque and Gingival Indices, probing pocket depths

and clinical attachment levels were assessed over a period of 3 months. Other outcomes of interest included patient compliance and oral hygiene practices. The study evaluated the benefits of adding AI-assisted oral hygiene support to routine periodontal treatment to better understand the clinical and behavioral outcomes of using the support.

METHODOLOGY

A randomized, controlled clinical study was conducted to test the effectiveness of an AI-based oral hygiene application in combination with scaling and root planing (SRP) for adult patients suffering from periodontitis. The study enrolled 120 patients within the age group of 25 to 55 years, who attended the dental outpatient department for periodontal evaluation and treatment. Participants were enrolled using the consecutive sampling method and only those patients who fulfilled the eligibility criteria were included in the study. The study population comprised of both male and female patients suffering from clinically diagnosed periodontitis, who were in need for nonsurgical periodontal therapy. Written informed consent was obtained from all patients prior to enrollment and the study procedures were explained in detail to them.

The study included patients aged between 25 to 55 years, who were clinically diagnosed with periodontitis and had adequate natural teeth for periodontal assessment and who were willing to attend follow-up visits for a period of 3 months. Patients who were diagnosed with systemic conditions which could impact periodontal health, for e.g. uncontrolled Diabetes and Immunocompromised conditions were excluded. Additionally, pregnant and lactating women, patients who were assessed within the last 3 months and received periodontal therapy, patients who were on systemic antibiotics within the last 3 months, patients who required an immediate surgical periodontal therapy, and patients who did not wish to use the AI-based application and support for oral hygiene were excluded.

The study included 120 participants who were randomized into the two groups, each having 60 participants. The random allocation was performed on a computer-based randomization sequence to avoid selection bias and for balancing the groups. The group I served as conventional treatment group and the group II served as AI treatment group. Group I participants were treated with scaling and root planing along with the routine oral hygiene instructions. The participants of group II were treated with scaling and root planing along with the AI-based oral hygiene intervention. All the participants were treated with a basic periodontal treatment to ensure standardization.

Participants were evaluated for Medical and Dental History. Demographic data of the participants, i.e. age, sex, ethnicity, education and occupation were collected. A comprehensive intraoral examination was performed to evaluate periodontal health, and assess the severity of periodontal inflammation. Clinical periodontal measurements were carried out to assess the patient at baseline before any intervention. Plaque index was conducted to evaluate the presence of dental plaque. Gingival index was evaluated for the level of inflammation. Probing pocket depth was measured to access the severity of periodontal inflammation. Measurement of clinical attachment level was done by assessing the distance of pocket from the base of the tooth and the cementum. The pocket depth measurements were recorded for the selected sites on the tooth and the mean for each participant was calculated.

All patients received nonsurgical periodontal treatment as per their allocated group. Scaling and root planing (SRP) were carried out using conventional periodontal instruments and ultrasonics by a trained dental professional. Subgingival root surface debridement was done to remove various deposits and calculus and to decrease local irritants. The same treatment was implemented on both groups to standardize treatment and reduce variability of clinical management. In addition, participants were also educated on proper methods of toothbrushing, the importance of interdental cleaning, and of practicing daily oral hygiene methods.

Participants of Group I were educated on conventional methods of oral hygiene through verbal teachings and periodic educational materials, and were instructed to practice proper toothbrushing and interdental cleaning techniques, to maintain twice daily tooth brushing, and provided general information on plaque control and periodontal maintenance. No artificial intelligence (AI) based, digital monitoring and personalized application based reminders, were offered to this group during the study.

Participants in Group II benefitted from additional support in the form of an Artificial Intelligence (AI) based oral hygiene application

(Dentulu) on their smartphones. The application functioned as a coaching and support application to provide personalized oral hygiene advice and brushing instruction, educational content, and prompts to reinforce positive oral hygiene behaviors. The participants were trained on the application and its features prior to initiating the intervention. The application was set to remind participants to perform oral hygiene practices and to provide individualized advice based on their recorded oral hygiene practices. The educational content of the application focused on improving participants' awareness of the signs of plaque, gingival inflammation, as well as prevention of periodontal diseases and the importance of maintaining oral hygiene after a professional periodontal treatment. Participants were encouraged to use the application to improve their oral hygiene practices during the three-month follow-up period.

All participants were assessed at baseline and after three months of the intervention. At the end of the three-month period, a repeat of the baseline clinical periodontal examination was performed. Assessments of Periodontal Health included re-evaluation of Plaque and Gingival Indices, probing pocket depths and clinical attachment levels. Patient compliance and oral hygiene practices were assessed using a questionnaire. The questionnaire assessed such practices as regular and twice daily toothbrushing as well as adherence to oral hygiene practices and instruction. In addition, treatment compliance was assessed by participants' reported adherence to follow-up and oral hygiene practices instructions.

The data was entered into the Statistical Package for the Social Sciences (SPSS) version 26 for statistical analysis. Descriptive statistics were calculated for the demographic and the clinical periodontal parameters. Frequencies and percentages were presented for the categorical variables like gender, level of education, and patient compliance. Mean and standard deviation were used to present the continuous variables such as Plaque and Gingival Indices, probing pocket depth and clinical attachment level. Independent samples t-test was used to compare the study groups for their baseline characteristics and clinical periodontal measurements. The paired samples t-test was used to evaluate changes in the clinical periodontal measurements for each group from baseline to the three-month follow up. The independent samples t-test was used to compare mean changes between the study groups. Chi-square test was used to analyze the differences in compliance of the patients and oral hygiene practices. A p-value of less than 0.05 was considered statistically significant.

Written informed consent was obtained prior to data collection. We ensured the confidentiality of participants' personal and clinical information and the data collected were used solely for research. Participants were informed about the study procedures, potential benefits, and their right to withdraw from the study at any time without affecting their right to continue to receive dental treatment.

RESULTS

120 patients were included with the diagnosis of periodontitis in the study. Each of the participants was assigned to one of the two groups based on their inclusion in the study. Group I patients received conventional therapy which consisted of scaling and root planing (SRP) plus routine oral hygiene instructions. Group II patients also received SRP plus an AI-based oral hygiene application. Clinical parameters of periodontitis were re-evaluated three months after the therapy. Both groups improved in periodontal health; however, the AI group was more improved.

Table 1. Demographic Characteristics of Study Participants (N = 120)

Variables	Group I (n=60)	Group II (n=60)	Total (N=120)
Age (years)			
25–35	24 (40.0%)	26 (43.3%)	50 (41.7%)
36–45	22 (36.7%)	20 (33.3%)	42 (35.0%)
46–55	14 (23.3%)	14 (23.3%)	28 (23.3%)
Gender			
Male	32 (53.3%)	30 (50.0%)	62 (51.7%)
Female	28 (46.7%)	30 (50.0%)	58 (48.3%)
Educational Status			
Primary	12 (20.0%)	10 (16.7%)	22 (18.3%)
Secondary	21 (35.0%)	23 (38.3%)	44 (36.7%)
Graduate	19 (31.7%)	18 (30.0%)	37 (30.8%)

Postgraduate	8 (13.3%)	9 (15.0%)	17 (14.2%)

Values are presented as frequency and percentage.

Interpretation: Most participants were in the 25-35 age group (41.7%). 51.7% of the total sample was male, and 48.3% was female. The demographic characteristics of the two groups were fairly comparable.

Table 2. Comparison of Baseline Clinical Periodontal Parameters between Study Groups

Clinical Parameters	Group I (n=60) Mean ± SD	Group II (n=60) Mean ± SD	p-value
Plaque Index	1.79 ± 0.39	1.82 ± 0.42	0.687
Gingival Index	1.61 ± 0.40	1.64 ± 0.38	0.672
Probing Pocket Depth (mm)	5.38 ± 0.81	5.42 ± 0.76	0.781
Clinical Attachment Level (mm)	5.15 ± 0.79	5.18 ± 0.83	0.834

Independent samples t-test was applied. P-value <0.05 was considered statistically significant.

Interpretation: In the baseline periodontal parameters, there was no statistically significant difference between the two groups (p>0.05). Thus, the two groups did not differ in their periodontal conditions prior to treatment.

Table 3. Within-Group Comparison of Clinical Periodontal Parameters at Baseline and Three-Month Follow-Up

Clinical Parameters	Group	Baseline Mean ± SD	3-Month Mean ± SD	p-value
Plaque Index	Group I	1.79 ± 0.39	1.05 ± 0.31	<0.001
	Group II	1.82 ± 0.42	0.72 ± 0.25	<0.001
Gingival Index	Group I	1.61 ± 0.40	0.89 ± 0.27	<0.001
	Group II	1.64 ± 0.38	0.61 ± 0.22	<0.001
Probing Pocket Depth (mm)	Group I	5.38 ± 0.81	3.68 ± 0.62	<0.001
	Group II	5.42 ± 0.76	3.12 ± 0.54	<0.001
Clinical Attachment Level (mm)	Group I	5.15 ± 0.79	3.62 ± 0.57	<0.001
	Group II	5.18 ± 0.83	3.21 ± 0.51	<0.001

Paired samples t-test was applied for within-group comparisons.

Interpretation: Both groups showed significant improvements for all clinical periodontal parameters at the 3 month follow up. The AI group, however, showed greater reductions for all parameters including plaque and gingival inflammation, probing pocket depth, clinical attachment level and other clinical parameters.

Table 4. Between-Group Comparison of Clinical Periodontal Parameters at Three-Month Follow-Up

Clinical Parameters	Group I Mean ± SD	Group II Mean ± SD	t-value	p-value
Plaque Index	1.05 ± 0.31	0.72 ± 0.25	6.40	<0.001
Gingival Index	0.89 ± 0.27	0.61 ± 0.22	6.22	<0.001
Probing Pocket Depth (mm)	3.68 ± 0.62	3.12 ± 0.54	5.26	<0.001
Clinical Attachment Level (mm)	3.62 ± 0.57	3.21 ± 0.51	4.10	<0.001

Independent samples t-test was applied.

Interpretation: At the 3-month follow-up, Group II showed much better periodontal outcome data than Group I. There were statistically significant differences for all four clinical parameters (P< 0.001).

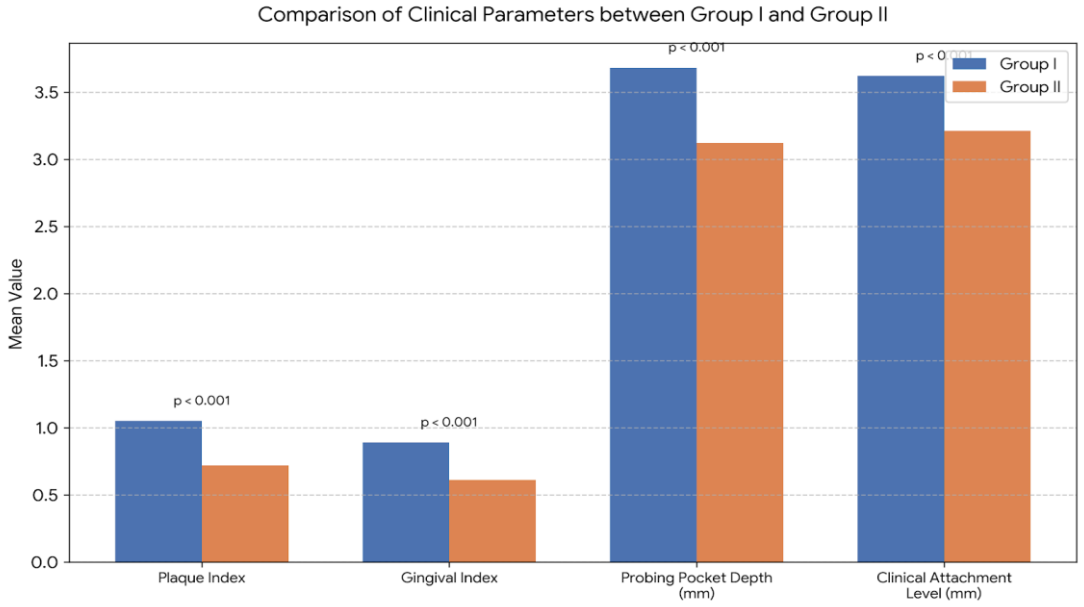


Table 5. Comparison of Mean Changes in Clinical Periodontal Parameters between Study Groups

Clinical Parameters	Group I Mean Change ± SD	Group II Mean Change ± SD	p-value
Plaque Index	0.74 ± 0.29	1.10 ± 0.34	<0.001
Gingival Index	0.72 ± 0.30	1.03 ± 0.31	<0.001
Probing Pocket Depth (mm)	1.70 ± 0.59	2.30 ± 0.65	<0.001
Clinical Attachment Level (mm)	1.53 ± 0.52	1.97 ± 0.58	<0.001

Positive values indicate improvement (reduction in clinical measurements). Independent samples t-test was applied to mean change scores.

Interpretation: The mean reduction in all clinical periodontal parameters was significantly greater in Group II than in Group I. The largest improvement was observed in probing pocket depth, with a mean reduction of 2.30 ± 0.65 mm in the AI-assisted group compared with 1.70 ± 0.59 mm in the conventional treatment group.

Table 6. Comparison of Patient Compliance and Oral Hygiene Practices Between Study Groups

Variables	Group I (n=60)	Group II (n=60)	p-value
Regular tooth brushing	43 (71.7%)	55 (91.7%)	0.005
Brushing twice daily	39 (65.0%)	53 (88.3%)	0.003
Regular interdental cleaning	25 (41.7%)	44 (73.3%)	0.001
Adherence to oral hygiene instructions	39 (65.0%)	53 (88.3%)	0.003
Overall treatment compliance	39 (65.0%)	53 (88.3%)	0.003

Values are presented as frequency and percentage. Chi-square test was applied. P-value <0.05 was considered statistically significant.

Interpretation: Patient compliance and oral hygiene practices were considerably better in Group II than in Group I. The AI-assisted group demonstrated better adherence to regular brushing, twice-daily brushing, interdental cleaning and overall compliance to oral hygiene instructions**.**

DISCUSSION

This study examined the potential benefits of integrating an artificial intelligence (AI) based oral hygiene application with scaling and root planing (SRP) for adult patients with periodontitis. The results included in the study demonstrated that the AI-assisted group demonstrated better improvements in the periodontal parameters and compliance with oral hygiene in comparison to the conventional treatment group. The differences emphasized the value of combining professional periodontal treatment with patient education and behavioral support. The extent of these differences should be further examined with the actual patient-level data, as well as in the context of an adequate statistical analysis.

Decreased plaque accumulation in the AI-assisted group may be related to the application reinforcing oral hygiene instructions and reminders. A recent systematic review by Doceda, Petit, and Huck, reviewed behavioral interventions to improve oral hygiene in individuals with periodontal disease. The review highlights the role of behavioral and individualized education in plaque control and health of the gums. Although the review supports the use of digital aids in periodontal care, it does not support that all AI applications in this field are effective (11).

Improvement in gingival health and better adherence to recommended brushing and interdental cleaning may be related to the interaction effect in the personalized digital aid in periodontal care. Dimenäs and colleagues assessed a theory-based behavioral intervention in adolescents and reported improvements in plaque, gingival scores, and bleeding as well as in oral hygiene behavior when compared to conventional education. Improved gingival health may be attributed to a personalized approach in interaction with AI and may show potential in adult patients receiving SRP (12).

The combined effects of professional periodontal debridement, home oral hygiene practices, and digital aids in periodontal care may contribute to improved clinical attachment and reduction in probing pocket depths. Moore and colleagues have also investigated the use of an interdental brush with a tracking device in periodontal patients. Their randomized clinical trial assessed clinical periodontal parameters and inflammatory biomarkers, highlighting the role of effective interdental cleaning in periodontal health. As such, interdental hygiene education can be incorporated in additional periodontal therapies, though the study does not prove the efficacy of AI-based applications (13).

Another randomized clinical trial adds to the evidence of the benefits of home care after SRP. This study compared the use of powered and manual toothbrushes on patients with Stage I and Stage II periodontitis. The study found that participants in the powered toothbrush group had better clinical attachment gain and reductions in probing depth and plaque compared to the manual toothbrush group. Further, the study found that the benefits of powered toothbrush use was evident up to 3-months post-treatment. These results highlight that, along with plaque control maintenance, patient education on home care practices post-SRP is essential for sustained benefits of periodontal treatment. However, the effects of a powered toothbrush cannot be directly compared to an AI-based application, because the components and mechanisms of action are different (14).

Behavioral management was found to be effective when combined with educational strategies. A behavioral intervention study by Donos and colleagues focused on adults with mild-to-moderate periodontitis found that, though both the intervention and control groups showed improvements in periodontal parameters, the intervention group did not show better improvements compared to the control group, suggesting that educational and motivational support may be helpful, but its effect depends on the frequency of support, and patient engagement. In addition, when considering the evidence from this study and those previously mentioned, it can be concluded that an application focused on oral hygiene should be assessed on clinical benefits and sustained use rather than just the use of the application (15).

From the reviewed literature, the key elements to effective periodontal treatment and management remain to be patient education, effective home plaque control, and behavioral support. It may be possible to use AI-based applications to deliver some of the elements of care between clinical visits. However, the

existing data do not allow us to generalize that every digital intervention results in better outcomes. The effectiveness of the intervention should be demonstrated by the use of valid clinical measurements and statistical comparisons, and by a longer follow-up to evaluate whether the effects of the intervention are sustained.

CONCLUSION

Based on the findings of this randomized clinical trial, the integration of an AI-based oral hygiene application could enhance oral hygiene habits and adherence to treatment and, therefore, support scaling and root planing (SRP) procedures. The results of this randomised clinical trial demonstrated that the use of AI to assist patients in improving their oral hygiene habits may achieve better periodontal outcomes.

Future Suggestions

Studies should explore the sustainability of improvements in periodontal health in larger and more diverse populations using follow-up periods longer than the 3 months studied herein. Future studies should use validated clinical indices, standardize the protocol of the application, and utilize objective measures of user engagement. Statistical analyses should also be performed. Multicentre randomized controlled trials would help determine whether AI-assisted oral hygiene support brings any added value in comparison to conventional periodontal treatment and care.

Limitations of Study

Because of the short follow-up duration (3 months), the long-term maintenance of the improvement of the periodontal health of the study participants could not be assessed. It should be considered that participants differ in their motivation, adherence to the use of the application, and the use of the application, as well as their compliance with the recommendations for oral hygiene. The study focused on a specific AI-assisted approach, and as such its generalizability to other digital platforms is unknown.

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