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Original Article

Mobile App-Supported Periodontal Treatment: A Randomized Trial on Clinical and Cognitive Outcomes

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ABSTRACT

The objective of this research was to explore the variations in clinical, cognitive, and psychomotor performance among individuals diagnosed with gingivitis or periodontitis when assisted by a smartphone-based application. Forty participants were selected randomly and divided equally into two groups—control and experimental—both of which underwent professional mechanical plaque removal (PMPR). The clinical factors evaluated included bleeding on probing (BoP), probing pocket depth (PPD), and the simplified oral hygiene index (OHI-S). The experimental group utilized a mobile app named PerioUICare, which offered constant guidance, education, motivation, and daily hygiene alerts. Mean score comparisons were conducted between groups (inter-group) and within each group (intra-group) after one and three months. At the one-month assessment, notable inter-group differences appeared in BoP, PPD, cognitive, and psychomotor measures among gingivitis patients, and in BoP, OHI-S, cognitive, and psychomotor measures among those with periodontitis. After three months, significant differences persisted in all parameters except PPD for the periodontitis group. Intra-group analysis indicated statistically meaningful changes in every parameter for the test group, while the control group showed no relevant improvement in cognitive or psychomotor outcomes. Findings suggest that integrating a mobile app into periodontal care enhances treatment effectiveness.

Keywords: Mobile health tools, Periodontitis, Periodontal evaluation, Dental science, Oral care

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Introduction

Periodontal disorders—including gingivitis and periodontitis—represent inflammatory infections linked to microbial plaque imbalance and immune reactions that cause soft and hard tissue damage [1]. According to the Global Burden of Disease Study, periodontitis is ranked the sixth most prevalent illness worldwide, affecting roughly 11.2% of the global population—about 743 million people—and continues to require increasing treatment attention [2]. The American Academy of Periodontology (AAP) and the European Federation of Periodontology (EFP) recently redefined periodontal disease classifications based on both severity and complexity (staging) and risk of advancement (grading) [1]. Gingivitis typically manifests through bleeding, redness, and swelling, and if untreated, may lead to tissue destruction, pocket formation, and attachment loss [3, 4]. Consequently, bleeding on probing (BoP) and probing pocket depth (PPD) are key diagnostic indicators, while the presence or absence of clinical attachment loss (CAL) differentiates gingivitis from periodontitis [1, 3, 4]. Moreover, the simplified oral hygiene index (OHI-S) has been shown to correlate with disease occurrence; individuals with moderate to poor OHI-S levels are two to five times more prone to develop periodontitis [5].

Proper management of periodontal disease demands awareness of its causes, risk factors, and pathogenesis, along with knowledge of treatment stages [6]. The initial phase centers on changing patient behavior through education and motivation to eliminate supragingival biofilm and manage risk elements. This involves cognitive understanding and psychomotor skills for maintaining oral cleanliness [7]. Studies suggest that such behavioral outcomes can be evaluated effectively over a three-month intervention [8, 9]. Hence, this research analyzed the effect of a periodontal mobile application as an auxiliary method for teaching, motivating, and reminding patients to maintain oral hygiene over one- and three-month intervals, following supragingival scaling or PMPR [6, 7]. Additionally, research by Scribante *et al.* confirmed that minimally invasive methods—like photodynamic therapy

(PDT), photobiomodulation (PBM), and ozone therapy—may decrease periodontal inflammation [10, 11]. This concept of conservative periodontal treatment served as part of the rationale for this study.

Smartphones—devices that integrate computing, communication, and multimedia capabilities—have become an essential global technology [12, 13]. They have reshaped sectors ranging from commerce and education to healthcare [12]. Their universal use across age groups highlights their role in influencing lifestyle habits and improving quality of life [13, 14]. Beyond convenience and accessibility, smartphones enable health monitoring through mobile apps, allowing clinicians to follow patient progress remotely and reduce in-person visits [15, 16].

The use of mobile health applications has rapidly expanded in medicine [12–19]. Tobias *et al*. employed smartphone "dental selfies" to identify gingivitis using the modified gingival index (MGI) [16]. Alkadhi *et al*., in a randomized trial, demonstrated that orthodontic patients achieved better oral hygiene outcomes when using such applications [17]. Likewise, Ng *et al*. showed that educational web tools improved denture and oral hygiene [18]. However, only limited evidence exists on the impact of mobile technologies for managing periodontal disease. Therefore, this randomized controlled study aimed to determine how mobile app–assisted periodontal therapy influences clinical markers (BoP, PPD, OHI-S) and cognitive and psychomotor outcomes in patients with gingivitis and periodontitis.

Materials and Methods

Study design

This work adopted a double-blind, randomized, and controlled clinical design. A total of 40 participants diagnosed with periodontal conditions were randomly and equally assigned to either an experimental or a control group at the Periodontics Clinic, Dental Teaching Hospital, Faculty of Dentistry, Universitas Indonesia, during the period April 2021 – December 2022. Ethical authorization was granted by the Dental Research Ethics Committee of the same faculty (Approval No. 01/Ethical Approval/FKGUI/I/2022, Protocol No. 091241221).

Before any procedures began, each participant was fully informed about the study's purpose, sequence of procedures, the mobile-app component, possible benefits and drawbacks, and confidentiality guarantees. Only individuals who clearly understood the explanation and voluntarily signed written consent were enrolled. All methods adhered to the revised Declaration of Helsinki and followed CONSORT reporting standards [20]. The study was officially registered under ISRCTN12409366 (https://doi.org/10.1186/ISRCTN12409366).

Study population

Eligibility criteria were:

1. a clinical diagnosis of gingivitis or periodontitis;
2. (2) 35 – 55 years of age;
3. absence of any professional periodontal treatment within the previous six months;
4. ownership of an Android-based smartphone.

Exclusion criteria included

1. presence of systemic diseases linked to periodontal pathology—such as cardiovascular illness, oral malignancy, respiratory infection, or type 2 diabetes;
2. pregnant or nursing individuals;
3. current use of prescribed drugs;
4. active tobacco use [21].

Participant characteristics are summarized in **Table 1**.

Table 1. The results of quantum-chemical calculations

Group	Intervention Group (n = 20)	Control Group (n = 20)
Age ± SD (years)	46.45 ± 6.863	43.90 ± 7.532
Education Level		
High School	14	12
Undergraduate Degree	6	8
Periodontal Condition		
Gingivitis	12	10
Periodontitis	8	10

Of the 61 individuals screened, 21 were excluded for not meeting the inclusion standards (n = 8), declining to join (n = 8), or missing their first appointment (n = 5). Consequently, 40 participants were finally randomized into a test group (n = 20) and a control group (n = 20), as shown in **Figure 1**.

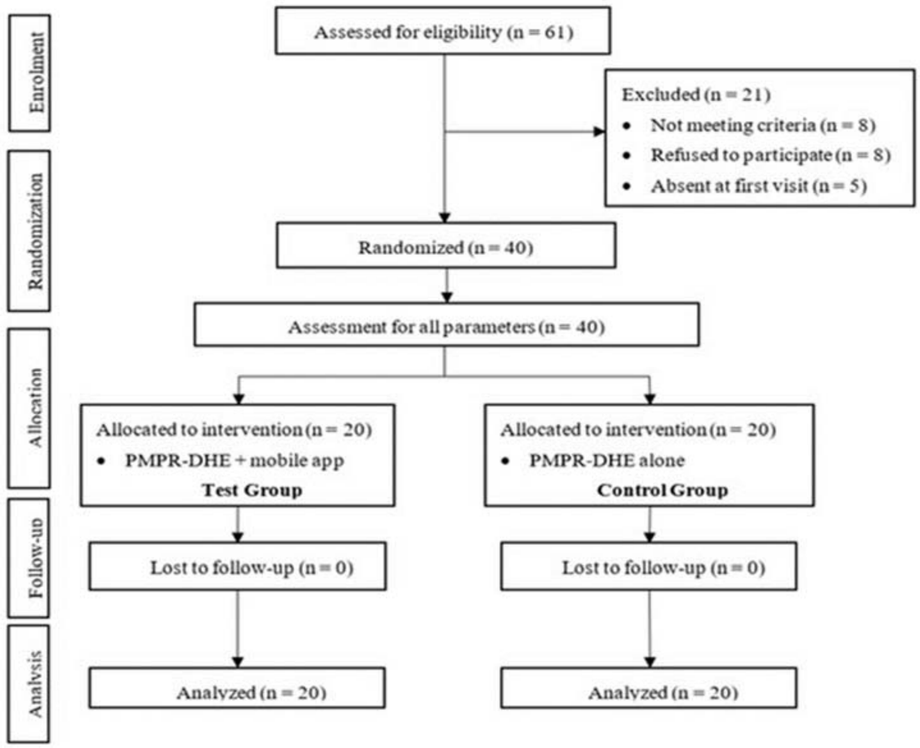


Figure 1. CONSORT-based flowchart of the randomized controlled trial.

Clinical examinations

All evaluations—covering both clinical and behavioral aspects—were performed by two blinded, calibrated postgraduate residents in periodontology. Baseline data collection included bleeding on probing (BoP), probing pocket depth (PPD), and the simplified oral hygiene index (OHI-S), measured with a UNC-15 periodontal probe (Hu-Friedy, Chicago, IL, USA).

PPD values were recorded at six sites per tooth—distobuccal, mid-buccal, mesiobuccal, distolingual, mid-lingual, and mesiolingual—excluding third molars. The mean probing depth per tooth was then calculated [22, 23]. BoP was observed during probing, noting any bleeding within 30 seconds. A disclosing gel (GC Tri Plaque ID Gel, GC Corporation, Tokyo, Japan) highlighted plaque deposits for the OHI-S assessment [24].

Periodontal status was classified as follows:

- Gingivitis = BoP ≥ 10%, PPD ≤ 3 mm, and absence of interdental CAL.
- Periodontitis = BoP ≥ 10%, PPD > 3 mm, with interdental CAL affecting at least two non-adjacent teeth [25].

Reliability testing for BoP and PPD employed the intraclass correlation coefficient (ICC). The two examiners each achieved near-perfect consistency (BoP = 0.998 and 0.999; PPD = 1.000 for both). Inter-examiner reliability was likewise excellent (BoP = 0.995; PPD = 1.000).

Cognitive ability was measured through questionnaires administered before and after the intervention, while psychomotor performance was rated with a validated oral-care checklist. The full versions of these instruments are provided in the supplementary materials.

Clinical and behavioral evaluations occurred at baseline, one month, and three months after app deployment. Data were entered by a trained operator into a secure back-end website linked to the periodontal app database.

Sample size calculation

Sample estimation was performed using G*Power v3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) [26]. Parameters were set at an effect size of 0.8, $\alpha = 0.05$, and power = 0.8 for two independent groups with a continuous main outcome. The computation indicated that 12 subjects per group were the minimum required.

Given the primary endpoint (PPD), an expected mean difference of 0.130510, and a 20% anticipated attrition rate, the study finally recruited 20 participants per group. The two arms were defined as:

- Experimental group: PMPR + DHE + mobile-app support.
- Control group: PMPR + DHE only.

Altogether, 40 participants were evaluated at three timepoints—baseline, one month, and three months. The sample verification was also run using the ClinCalc

Sample Size Calculator (ClinCalc LLC, Chicago, IL, USA).

Randomization

A pool of forty participants was compiled and separated evenly into two categories: a trial cohort (receiving PMPR-DHE combined with a mobile-app aid) and a comparison cohort (receiving PMPR-DHE only). Allocation was handled by an independent staff member who took no part in the examinations. A systematic randomization rule was applied—subjects bearing odd identification numbers entered the trial group, whereas those with even numbers were placed in the control arm [10]. Both the operator providing treatment and the individual processing the data remained blind to group identity, eliminating the possibility of assessment bias.

Treatment and interventions

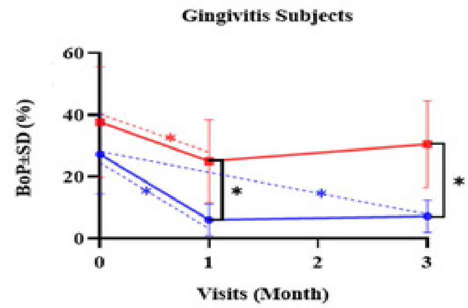
Following baseline recording of clinical indices together with cognitive and psychomotor evaluations, all enrollees underwent professional mechanical plaque removal (PMPR) and dental health education (DHE). These procedures were delivered by a trained postgraduate resident in periodontology who was masked to participant grouping.

Only the trial group received the digital adjunct, which relied on a smartphone tool titled PerioUICare (Universitas Indonesia, Jakarta). Participants were first guided through installation and account creation. During each appointment, their most recent periodontal findings were uploaded and could be viewed through the app, allowing them to track improvement or relapse. The program also issued daily prompts reminding users to clean their teeth, offered educational segments, and supplied motivational messages related to gum health.

Users received demonstrations on proper brushing motions and on applying interdental brushes and floss, synchronized with two automated reminders per day—one in the morning and one at night. In addition, the application delivered three weekly learning updates using interactive visual posters to reinforce self-care routines.

Statistical analysis

Data normality was examined through the Shapiro–Wilk procedure, revealing a mixture of normal and skewed distributions. Accordingly, both parametric and non-parametric statistical techniques were used. Between-group contrasts were assessed via independent-samples t-tests and Mann–Whitney U analyses, while within-group progress across time was tested using repeated-measures ANOVA and the Friedman approach for parametric and non-parametric datasets, respectively **(Tables 2 and 3)**. Pairwise differences between observation points were subsequently analyzed using a Bonferroni-corrected post-hoc test **(Figures 2-6)**. All computations were performed in SPSS v26.0 for Windows (IBM Corp., Chicago, IL, USA) with statistical significance defined as $p < 0.05$. Graphical displays were created using Prism v9.0.0 (GraphPad Software, Boston, MA, USA)



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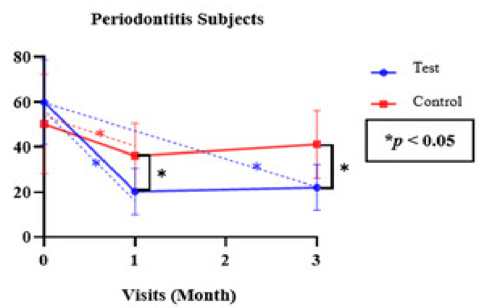

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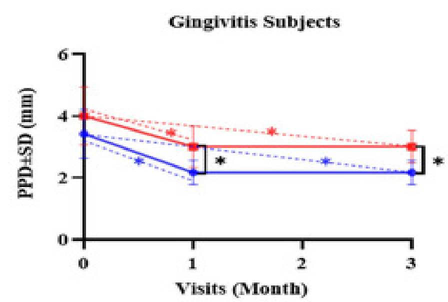
Figure 2. Progression of mean BoP values in both groups over time.



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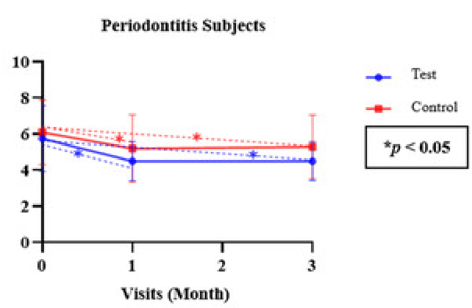

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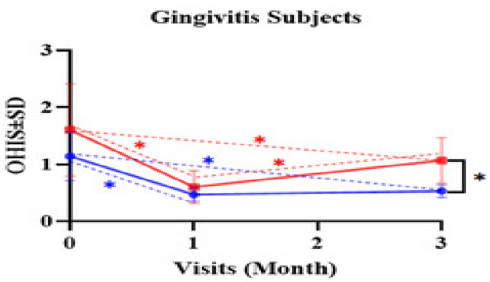
Figure 3. Progression of mean PPD values in both groups over time.



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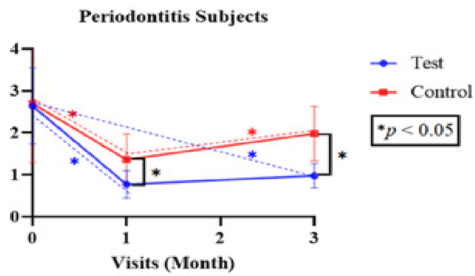

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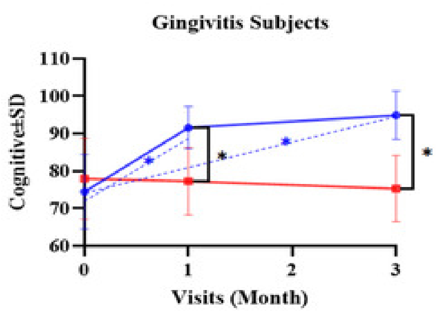
Figure 4. Progression of mean OHI-S values in both groups over time.



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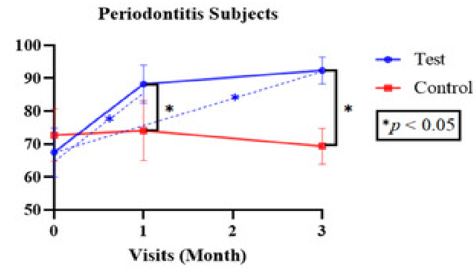

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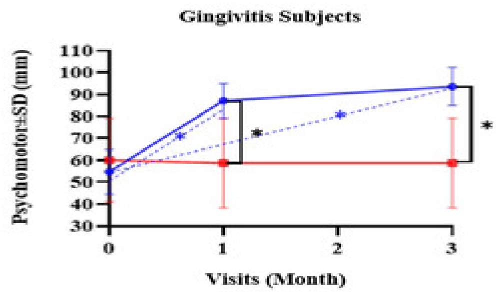
Figure 5. Progression of mean cognitive scores in both groups over time.



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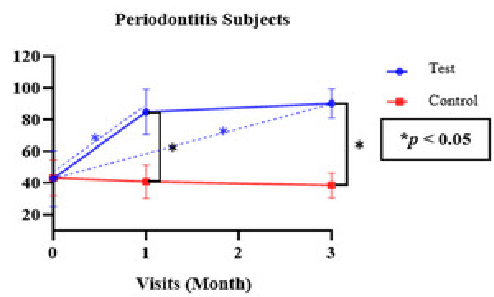

b)

Figure 6. Progression of mean psychomotor scores in both groups over time.

Table 2. Between-group comparison results at baseline and follow-ups in gingivitis participants.

Parameter	Group	Baseline	p-Value	1 Month	p-Value	3 Months	p-Value
Bleeding on Probing ± SD (%)	Intervention (n = 20)	27.27 ± 12.94	0.180 δ	6.04 ± 5.08	0.001 † *	7.22 ± 5.26	0.000 † *
	Control (n = 20)	37.62 ± 17.98		24.99 ± 13.44		30.48 ± 14.05	
Probing Pocket Depth ± SD (mm)	Intervention (n = 20)	3.42 ± 0.79	0.203 δ	2.17 ± 0.39	0.007 δ *	2.17 ± 0.39	0.000 δ *
	Control (n = 20)	4 ± 0.94		3 ± 0.67		3.5 ± 0.53	
Oral Hygiene Index ± SD	Intervention (n = 20)	1.14 ± 0.43	0.127 †	0. Lactobacillus ± 0.12	0.283 δ	0.53 ± 0.11	0.002 † *
	Control (n = 20)	1.60 ± 0.81		0.6 ± 0.29		1.07 ± 0.4	
Cognitive Score ± SD	Intervention (n = 20)	74.5 ± 9.94	0.438 †	91.58 ± 5.65	0.000 † *	94.92 ± 6.43	0.000 † *
	Control (n = 20)	78 ± 10.8		77.3 ± 8.99		75.3 ± 8.82	

Psychomotor Score ± SD	Intervention (n = 20)	54.75 ± 10.18	0.674 δ	87.17 ± 7.9	0.001 δ *	93.58 ± 8.72	0.000 δ *
	Control (n = 20)	60.1 ± 19.05		58.8 ± 20.46		58.8 ± 20.46	

† Independent-samples t-test (parametric); δ Mann–Whitney U (non-parametric); * $p < 0.05$ = significant.

Table 3. Within-group comparison results at baseline and follow-ups in gingivitis participants.

Parameter	Group	Initial Measurement	1 Month Follow-Up	3 Months Follow-Up	p-Value
Bleeding on Probing ± SD (%)	Intervention (n = 20)	27.27 ± 12.94	6.04 ± 5.08	7.22 ± 5.26	0.000 # *
	Control (n = 20)	37.62 ± 17.98	24.99 ± 13.44	30.48 ± 14.05	0.001 ^ *
Probing Pocket Depth ± SD (mm)	Intervention (n = 20)	3.42 ± 0.79	2.17 ± 0.39	2.17 ± 0.39	0.000 ^ *
	Control (n = 20)	4 ± 0.94	3 ± 0.67	3.5 ± 0.53	0.005 ^ *
Oral Hygiene Index ± SD	Intervention (n = 20)	1.14 ± 0.43	0.47 ± 0.12	0.53 ± 0.11	0.000 ^ *
	Control (n = 20)	1.60 ± 0.81	0.6 ± 0.29	1.07 ± 0.4	0.000 # *
Cognitive Score ± SD	Intervention (n = 20)	74.5 ± 9.94	91.58 ± 5.65	94.92 ± 6.43	0.000 # *
	Control (n = 20)	78 ± 10.8	77.3 ± 8.99	75.3 ± 8.82	0.227 #
Psychomotor Score ± SD	Intervention (n = 20)	54.75 ± 10.18	87.17 ± 7.9	93.58 ± 8.72	0.000 ^ *
	Control (n = 20)	60.1 ± 19.05	58.8 ± 20.46	58.8 ± 20.46	1

Repeated-measures ANOVA (parametric); ^ Friedman (non-parametric); * $p < 0.05$ = significant.

Results and Discussion

The findings for every recorded variable across the different evaluation stages are summarized in **Tables 2–5**. All participants (n = 40) completed the trial successfully, with no complications or adverse effects observed during the study period.

Table 4. Comparative analysis between test and control groups at baseline and at each assessment period for individuals diagnosed with periodontitis.

Parameter	Group	Initial Assessment	p-Value	1 Month Follow-Up	p-Value	3 Months Follow-Up	p-Value
Bleeding on Probing ± SD (%)	Intervention (n = 20)	59.92 ± 18.77	0.340 †	20.30 ± 10.25	0.020 † *	22.04 ± 10.27	0.008 † *
	Control (n = 20)	50.24 ± 22.15		36.07 ± 14.56		41.18 ± 15.10	
Probing Pocket Depth ± SD (mm)	Intervention (n = 20)	5.75 ± 1.83	0.408 δ	4.5 ± 1.07	0.460 δ	4.5 ± 1.07	0.315 δ
	Control (n = 20)	6.1 ± 1.79		5.2 ± 1.87		5.3 ± 1.77	
Oral Hygiene Index ± SD	Intervention (n = 20)	2.64 ± 0.91	0.915 †	0.77 ± 0.33	0.043 δ *	0.98 ± 0.29	0.001 † *
	Control (n = 20)	2.7 ± 1.41		1.36 ± 0.61		1.98 ± 0.65	
Cognitive Score ± SD	Intervention (n = 20)	67.5 ± 7.43	0.175 †	88.25 ± 5.73	0.003 † *	92.38 ± 4.1	0.000 † *
	Control (n = 20)	72.7 ± 7.96		74.1 ± 9.16		69.4 ± 5.46	
Psychomotor Score ± SD	Intervention (n = 20)	42.88 ± 17.47	0.962 †	84.88 ± 14.33	0.000 † *	90.38 ± 9.18	0.000 δ *
	Control (n = 20)	43.2 ± 11.31		40.8 ± 10.59		38.5 ± 7.78	

† Independent t-test (parametric, inter-group); δ Mann–Whitney U test (non-parametric, inter-group); * $p < 0.05$ indicates statistical significance.

Table 5. Within-group comparison results at baseline and at subsequent evaluation points for participants with periodontitis.

Parameter	Group	Initial Measurement	1 Month Follow-Up	3 Months Follow-Up	p-Value
Bleeding on Probing ± SD (%)	Intervention (n = 20)	59.92 ± 18.77	20.30 ± 10.25	22.04 ± 10.27	0.000 # *
	Control (n = 20)	50.24 ± 22.15	36.07 ± 14.56	41.18 ± 15.10	0.024 # *
Probing Pocket Depth ± SD (mm)	Intervention (n = 20)	5.75 ± 1.83	4.5 ± 1.07	4.5 ± 1.07	0.002 ^ *
	Control (n = 20)	6.1 ± 1.79	5.2 ± 1.87	5.3 ± 1.77	0.001 ^ *
Oral Hygiene Index ± SD	Intervention (n = 20)	2.64 ± 0.91	0.77 ± 0.33	0.98 ± 0.29	0.001 ^ *
	Control (n = 20)	2.7 ± 1.41	1.36 ± 0.61	1.98 ± 0.65	0.01 # *
Cognitive Score ± SD	Intervention (n = 20)	67.5 ± 7.43	88.25 ± 5.73	92.38 ± 4.1	0.001 # *
	Control (n = 20)	72.7 ± 7.96	74.1 ± 9.16	69.4 ± 5.46	0.095 #
Psychomotor Score ± SD	Intervention (n = 20)	42.88 ± 17.47	84.88 ± 14.33	90.38 ± 9.18	0.000 # *
	Control (n = 20)	43.2 ± 11.31	40.8 ± 10.59	38.5 ± 7.78	0.174 ^

Repeated-measures ANOVA (parametric, intra-group); ^ Friedman test (non-parametric, intra-group); * p < 0.05 indicates statistical significance.

At baseline, there were no detectable differences between the control and experimental groups for any examined indicators. After one month, significant variations emerged: for patients with gingivitis, notable changes appeared in BoP (p = 0.001), PPD (p = 0.007), cognitive (p = 0.000), and psychomotor (p = 0.001) outcomes. Among participants with periodontitis, significant distinctions were recorded in BoP (p = 0.02), OHI-S (p = 0.043), cognitive (p = 0.003), and psychomotor (p = 0.000) results.

By the three-month follow-up, all tested variables demonstrated statistically significant improvements (p < 0.05) except PPD (p = 0.315) for those with periodontitis. Throughout the study, both control and test groups—irrespective of diagnosis—showed measurable progress in their clinical indices (p < 0.05). Yet, cognitive and psychomotor performance in the control group did not change significantly for participants with gingivitis (p = 0.227, p = 1.000) or periodontitis (p = 0.095, p = 0.174). Conversely, the test group showed clear and significant enhancement in these measures for gingivitis (p = 0.000, p = 0.000) and periodontitis (p = 0.001, p = 0.000) patients.

To determine where changes occurred between evaluation intervals, post hoc analyses were performed **(Figures 2–6)**.

As illustrated in **Figure 2**, mean BoP values declined significantly from baseline to one month within the test group (p = 0.000 for both gingivitis and periodontitis), remained stable from one to three months (p = 0.227, p = 0.119), and again decreased markedly when comparing baseline to three months (p = 0.001 for both conditions). In the control group, reductions in BoP were evident only between the baseline and the one-month check (p = 0.001 for gingivitis; p = 0.039 for periodontitis) **(Figure 2)**.

Figure 3 presents the trend in PPD averages for all participants. Within the test group, PPD values dropped significantly from baseline to one month (p = 0.007, p = 0.024), maintained stability between one and three months (p = 1.000, p = 1.000), and again showed a marked decline from baseline to three months (p = 0.007, p = 0.024).

A comparable progression occurred in the control group, except for a minor, statistically non-significant rise in PPD between the one- and three-month intervals (p = 0.943 for gingivitis; p = 1.000 for periodontitis) **(Figure 3)**.

The OHI-S pattern, shown in **Figure 4**, depicts changes in mean OHI-S values for both study arms and diagnostic categories. For the test participants, values dropped sharply between baseline and one month (p = 0.000, p = 0.001), remained almost unchanged from one to three months (p = 0.922, p = 0.401), and displayed an overall significant decrease across the entire period (p = 0.013, p = 0.037).

In the control cohort, individuals with gingivitis exhibited significant OHI-S improvement between baseline and both follow-ups (p = 0.000), though a rebound increase appeared between one and three months (p = 0.044). For periodontitis, this upward shift was also observed, but the change between baseline and three months did not reach significance (p = 0.259) **(Figure 4)**.

Figure 5 demonstrates the variations in average cognitive performance observed among individuals with gingivitis and periodontitis within both the experimental and control groups, measured at baseline, one month, and three months.

Following post hoc assessment, participants in the experimental group showed a statistically meaningful rise in mean cognitive results between baseline and the one-month follow-up (p = 0.007 for gingivitis; p = 0.037 for periodontitis). From one month to three months, the increase persisted but was not significant (p = 0.662 and p = 0.952). When comparing baseline to three months, a clear significant elevation was noted (p = 0.000 and p = 0.001). In contrast, the control cohort exhibited no measurable variation over time (p > 0.05).

Figure 6 presents the mean psychomotor performance scores among participants with gingivitis and periodontitis for both test and control categories at initial, one-month, and three-month intervals. In the test sample, post hoc findings indicated a significant improvement from baseline to one month (p = 0.009, p = 0.001), followed by a non-significant rise from one month to three months (p = 0.459, p = 0.099). Comparing baseline to three months, the enhancement remained highly significant (p = 0.000, p = 0.000). The control participants, however, did not show any significant progression across the same duration (p > 0.05).

The management of periodontal conditions in this trial emphasized elimination of causative factors through PMPR, combined with reinforcement of patient motivation [27]. Sustaining periodontal health requires a customized and recurring educational framework, in which patients receive targeted oral hygiene instructions and consistent encouragement to improve their awareness of the disease and recognize the benefits of behavioral modification [28].

The current investigation followed this rationale, aiming to determine whether personalized and repetitive instruction via a mobile periodontal platform could enhance patients' cognitive and psychomotor capacities and thereby positively influence tissue health without the necessity for regular clinical visits.

As outlined in **Table 1**, a total of 40 individuals participated—20 per group (test and control). The mean ages were 46.45 ± 6.863 years for the experimental group and 43.90 ± 7.532 years for the controls. Since age is directly associated with periodontal prevalence, and older adults may encounter difficulties adopting modern digital tools [13, 14], the eligible age range was limited to 35–55 years to obtain a consistent population. Educationally, the test group included 14 participants with high-school diplomas and 6 with bachelor's degrees, while the control group consisted of 4 and 16, respectively.

Baseline evaluation of periodontal condition identified 12 gingivitis and 8 periodontitis patients in the test arm, compared to 10 of each diagnosis in the control arm. No further subclassification by stage or grade (per the AAP/EFP 2017 World Workshop) was applied, because all periodontitis stages I–IV and grades A–C require initial therapy per the EFP S3 clinical guideline, involving PMPR alongside instruction and motivation [7]. Thus, this project focused solely on comparing gingivitis and periodontitis categories to assess the general efficacy of a mobile-assisted periodontal program.

The mobile application utilized was exclusive to Android devices and could only be accessed through the Google Play Store, hence inclusion was limited to participants with Android smartphones. Another constraint stemmed from the app's inability to ensure full user engagement; consequently, clinical indicators and cognitive/psychomotor scores served as objective measures of actual participation.

Baseline inter-group comparisons of BoP, PPD, and OHI-S revealed the following:

for gingivitis, 27.27 ± 12.94, 3.42 ± 0.79, and 1.14 ± 0.43 in the test group, compared to 37.62 ± 17.98, 4 ± 0.94, and 1.60 ± 0.81 in the control group;

for periodontitis, 59.92 ± 18.77, 5.75 ± 1.83, and 2.64 ± 0.91 in the test, versus 50.24 ± 22.15, 6.1 ± 1.79, and 2.7 ± 1.41 in the control.

These baseline findings showed no statistically relevant disparities between the groups (p > 0.05).

After one month of intervention, participants with gingivitis exhibited a smaller average PPD in the test group compared with the control group. In addition, those with either gingivitis or periodontitis in the test group showed statistically significant reductions in mean BoP when compared to controls (p = 0.001 and p = 0.020, respectively, at the one-month check). At the three-month review, the BoP trend remained similar (p = 0.000 and p = 0.008 for gingivitis and periodontitis, respectively). For individuals with periodontitis, differences in PPD between groups were not statistically meaningful, which aligns with the explanation by Gul *et al*. (2022) that tissue breakdown in periodontitis leads to irreversible pocket formation and attachment loss—unlike gingivitis, where the tissue can recover after early management [29]. Treating remaining periodontal pockets generally requires a tertiary phase involving surgical steps such as open-flap debridement, followed by regenerative or resective methods depending on bone morphology [30, 31].

Inter-group comparisons demonstrated no significant variation in mean OHI-S scores between test and control subjects with gingivitis after one month (p = 0.283). However, at three months, the OHI-S difference became significant (p = 0.002). Among periodontitis patients, the mean OHI-S values differed notably at both one- and three-month assessments (p = 0.043 and p = 0.001, respectively). These outcomes are consistent with those reported by Marchetti *et al*. (2018), who found that mobile-based repetition of motivational and educational content can successfully improve oral hygiene [32]. More recent evidence indicates that smartphone tools can serve as supportive instruments in periodontal management, acting as sources of information and aids in promoting better self-care routines [33]. Poor hygiene performance is usually linked to limited understanding or improper techniques; when proper guidance and professional maintenance accompany personal efforts, periodontal therapy can become more effective [34].

Within each group, a one-month intervention led to a statistically significant decrease (p < 0.05) in mean BoP and PPD among gingivitis participants: 6.04 ± 5.08 and 2.17 ± 0.39 in the test group versus 24.99 ± 13.44 and 3 ±

0.67 in controls. A similar pattern was observed in periodontitis cases, where mean BoP and PPD dropped ($p < 0.05$) to 20.30 ± 10.25 and 4.5 ± 1.07 for the test group compared to 36.07 ± 14.56 and 5.2 ± 1.87 in the control group. Jentsch *et al*. (2019) attributed such changes to supra- and subgingival debridement, which positively affects both parameters [35]. Even without app-based support, both groups showed improvement, though the decline was notably greater among test participants [36–38]. Milosavljevic *et al*. (2021) emphasized that sustained patient motivation and tailored education are key components in achieving long-term therapeutic success [28].

At the three-month observation, BoP values slightly but non-significantly increased ($p > 0.05$): 7.22 ± 5.26 and 30.48 ± 14.05 for gingivitis, and 22.04 ± 10.27 and 41.18 ± 15.10 for periodontitis, in the test and control groups, respectively. The mean PPD in the test group remained unchanged at 2.17 ± 0.39 and 4.5 ± 1.07 for gingivitis and periodontitis, while in the control group, slight rises were seen (3.5 ± 0.53 and 5.3 ± 1.77; $p > 0.05$). According to Lang *et al*. (2018), such minor fluctuations are expected since some degree of chronic inflammation tends to persist in periodontal tissues, making completely healthy gingiva without redness, swelling, or BoP exceptionally uncommon [39].

A particularly notable observation was the consistent PPD across one- and three-month assessments among both gingivitis and periodontitis patients in the test group. This finding agrees with Arweiler *et al*. (2018), who reported that when pocket depth is ≤5 mm and patients have sufficient knowledge and manual skills, stable periodontal conditions can be maintained without additional treatment [40]. Nonetheless, this stability relies on proper instruction, professional motivation, and patient adherence [41].

The 2017 World Workshop on periodontal classification defines clinically healthy gingiva as having BoP under 10% [42]. In this study, mean BoP among gingivitis participants in the test group fell below this threshold after both one and three months, confirming the reversibility of gingivitis as explained by Murakami *et al*. (2017), who emphasized that proper biofilm removal restores health [43]. These outcomes suggest that a mobile app used as an educational and motivational adjunct represents an effective management strategy. In contrast, the control group's mean BoP did not decline below 10%, indicating persistence of gingival inflammation. Furthermore, Stein *et al*. (2018) demonstrated that regular reinforcement of oral hygiene education—similar to what is delivered via mobile platforms—can significantly lower plaque levels, the major etiologic factor of periodontal diseases [44].

The intra-group comparison showed a statistically significant change in the mean OHI-S scores within both the experimental and control groups among participants diagnosed with gingivitis and periodontitis after one and three months of intervention ($p < 0.05$). Comprehensive comprehension of daily oral care practices and consistent compliance with recall appointments play a vital role, as these aspects are directly associated with patients' awareness of sustaining long-term periodontal health [45]. Compared to traditional educational tools such as brochures, mobile applications provide enhanced advantages for sharing oral health information. This is primarily due to their built-in reminder notifications, which allow information and prompts to reach users anytime and anywhere [46]. Repeated educational messages and motivational reminders through these applications effectively encouraged patients to maintain better oral hygiene, contributed to treatment success, and minimized the number of clinical visits [18].

For inter-group comparison at baseline, the cognitive mean scores in the test and control groups were 74.5 ± 9.94 and 78 ± 10.8 for gingivitis, and 67.5 ± 7.43 and 72.7 ± 7.96 for periodontitis, respectively. No significant difference was observed between the two groups for either condition at the start of the study ($p > 0.05$). Following one and three months of intervention, however, inter-group analyses revealed significant differences in cognitive scores between the test and control groups for both gingivitis and periodontitis ($p = 0.000$ and $p = 0.003$ at one month; $p = 0.000$ and $p = 0.000$ at three months, respectively). The correlation between periodontal and cognitive conditions suggests that improved understanding and awareness of oral hygiene enable patients to maintain periodontal stability, while healthcare providers should ensure that their communication effectively conveys essential information [45, 47]. According to Stein *et al*. (2018), continuous motivation and repeated oral health education can significantly reduce plaque accumulation—the primary indicator of oral hygiene and a key factor in periodontal disease [44].

Within-group comparisons among participants with gingivitis and periodontitis indicated a significant improvement in cognitive scores within the test group after one and three months ($p < 0.05$), while the control group showed no significant change ($p > 0.05$). Individuals with periodontal issues need a clear understanding of their periodontal tissue status, emphasizing proper hygiene habits and consistent adherence to scheduled visits [45]. Cognitive knowledge has a critical role in maintaining adequate oral hygiene and in improving plaque control effectiveness [48].

At baseline, mean psychomotor scores were 54.75 ± 10.18 and 60.1 ± 19.05 for gingivitis in the test and control groups, and 42.88 ± 17.47 and 43.2 ± 11.31 for periodontitis, respectively. These results showed no significant inter-group differences in psychomotor performance before the intervention ($p > 0.05$). After one month, psychomotor scores in the test group improved significantly for both gingivitis and periodontitis, whereas the control group demonstrated a slight but non-significant decline. Consequently, the test group had considerably higher psychomotor mean values than the control group (p = 0.001 and p = 0.000 for gingivitis and periodontitis, respectively). At the three-month evaluation, psychomotor scores in the test group continued to increase, though not significantly, while the control group with gingivitis remained unchanged and the periodontitis group showed a minor non-significant decrease. At this stage, the test group still exhibited significantly greater psychomotor scores than the control group (p = 0.000 and p = 0.000 for gingivitis and periodontitis, respectively). These observations align with Petrauskiene *et al*. (2019), who reported that patients commonly demonstrate limited motivation and poor long-term compliance with oral hygiene maintenance [49]. Hence, the use of a periodontal mobile application may enhance patient engagement by providing individualized, repetitive reminders, motivational support, and educational resources [50-57].

The outcomes of this research were in line with the randomized controlled trial by Marchetti *et al*. (2018), who reported that delivering motivational and educational reinforcement at regular intervals through a mobile platform effectively strengthens patient understanding, as reflected in the significant variation of oral hygiene index values between experimental and control groups [32]. Likewise, Geisinger *et al*. (2019) emphasized that oral hygiene recommendations should be personalized, as clinical presentation and risk profiles differ across patients [58]. Consistent with these findings, the current study showed that a periodontal mobile application offering customized, repeated reminders and education led to a statistically significant rise in psychomotor scores among individuals with gingivitis and periodontitis after one and three months of intervention, with the test group outperforming the control.

Additional support came from Singla *et al*. (2019), who examined the effect of reinforced hygiene instructions on patients with fixed orthodontic appliances. Their results showed marked improvement in patients' cleaning skills, illustrated by significant declines in plaque index (PI) and gingival index (GI) values after four and eight weeks within the experimental group [59]. Likewise, Williams *et al*. (2018) compared traditional verbal instruction to computer-based guidance and found that the latter resulted in lower plaque levels, notably in participants aged 50 years or younger, whereas only verbal advice yielded less pronounced results [60].

From these findings, it can be inferred that long-term improvement in psychomotor performance requires continuous and personalized reinforcement. Motivation and education that are not periodically repeated appear insufficient to sustain progress [43, 45]. The current research utilized such periodic reinforcement through the mobile periodontal tool. Moreover, recently identified bioactive compounds have demonstrated beneficial influences on oral microbial balance and health [61]. These results agree with the observed increase in mean psychomotor scores among participants with gingivitis and periodontitis in the experimental group, while changes in the control group remained insignificant at both follow-ups. Future studies should explore combining digital interventions with the application of lysates and postbiotics, as these agents have been shown to modulate clinical and microbiological factors in periodontal care [62, 63]. Overall, the present results suggest that app-based periodontal support successfully enhances psychomotor behavior in affected individuals.

A limitation of this study was the narrow participant age range, confined mostly to young adults. Since mobile technologies are generally more intuitive for younger populations, future investigations should include older age groups to verify broader applicability. Another constraint was the relatively uniform educational background of the participants, which might have contributed to their rapid adaptation to digital tools. Individuals with higher education tend to adopt new health technologies more readily than those with less schooling.

Conclusion

Within the limits of this study, it can be concluded that integrating a mobile application into the first phase of periodontal treatment effectively improves clinical, cognitive, and psychomotor measures. Therefore, such applications could serve as adjunctive options in periodontal management. To implement this approach widely, coordination among health professionals, policymakers, and public health sectors is required so that mobile health solutions can become part of preventive and health-promotive programs for managing periodontal diseases.

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