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EFFECTS OF ARTIFICIAL INTELLIGENCE BASED DENTAL MONITORING® IN PATIENTS WITH PERIODONTITIS: A RANDOMIZED CONTROLLED TRIAL

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Abstract

Background

Remote digital monitoring during orthodontic treatment can help patients in improving their oral hygiene performance and reducing the number of appointments due to emergency reasons, especially in time of COVID-19 pandemic where non-urgent appointments might be discouraged.

Methods

Thirty patients scheduled to start an orthodontic treatment were divided into two groups of fifteen. Compared to controls, study group patients were provided with scan box and cheek retractor (Dental Monitoring®) and were instructed to take monthly intra-oral scans. Plaque Index (PI), Gingival Index (GI), Clinical Attachment Level (CAL) and Probing Pocket Depth (PPD) were recorded for both groups at baseline ,2 weeks and 3 months. Inter-group differences were assessed with Student's *t* test, intra-group differences were assessed with Paired T test (significance $\alpha = 0.05$).

Results

Reduction in PI, GI, PPD, and CAL after 2 weeks and 3 months from baseline in both the groups was seen; intergroup comparison showed more reduction in PPD and GI and more gain in CAL in Dental Monitoring Group after 3 months when compared with control Group.

Conclusions

Integration of a remote monitoring system during periodontal treatment was effective in improving plaque control and improving periodontal parameters. The present findings encourage periodontists to consider this technology to help maintaining optimal oral health of patients, especially in times of health emergency crisis.

Keyword : Patient Motivation , Periodontitis , Artificial Intelligence , Supportive Periodontal Therapy , Home Care

Introduction

Oral health is highly related to one's general health, well-being and quality of life [**1**]. Good oral hygiene protects an individual's oral health and serves as a foundation of overall health, whereas poor oral hygiene leads to such dental problems as tooth decay and periodontal diseases, which in turn affect daily life. Maintaining good oral hygiene can sustain chewing ability and prevent bad breath, thereby enhancing personal social interactions, self-confidence, and happiness [**2**]. However, the prevalence of oral diseases is extremely high. Almost 100% of adults and 60%–90% of schoolchildren worldwide suffer from dental caries [**3**]. Periodontal disease is a common dental disease in adults, with a global prevalence rate of 20%–50%, and severe periodontitis is the sixth most prevalent oral disease worldwide [**4**].

Good behavior in oral self-care is fundamental to maintaining one's oral health and an important personal responsibility [**5**]. It is well known that daily oral self-care can effectively improve oral health and prevent dental or periodontal diseases. However, a significant number of individuals still suffer greatly from oral diseases, primarily owing to incorrect or inadequate knowledge of and inappropriate skills in oral care [**5**]. Providing oral care knowledge and skills is thus necessary to establish good behavior and capability to enhance oral hygiene [**5**,**6**]. Dental practitioners provide patients with oral hygiene instructions (OHIs) according to the results of examination during dental visits; however, poor adherence to these instructions is one of the key factors that negatively affect the success of dental treatments [**7**,**8**]. The most common barrier to proper adherence to OHIs is memory burden, which refers to patients' difficulty with recalling much of the information that they had received [**9**,**10**]. Practical functions of interventions could significantly reduce this burden in patients with periodontal diseases and improve their adherence to OHIs [**10**,**11**].

The past decade has witnessed the popularization and ubiquity of mobile apps, which have been identified as useful intervention tools for improving the efficiency of individuals' self-care and speed of healthcare delivery [**5**,**6**,**10**,**12**]. The potential of app-based interventions in promoting health and well-being is ever increasing [**13**], and the number of health-related apps aiming to promote health behaviors has grown substantially as a result. More than 325,000 mobile health apps were available for download worldwide in 2017 [**14**], with an exponential growth [**15**]. However, the extent to which the content of these apps can facilitate behavioral change varies. Therefore, it is important to identify the factors that allow a health promotion app to successfully support changes in health behavior [**13**].

Behavioral change techniques are theory-based methods that have been reported to help individuals change their behaviors to achieve better health [**12**,**16**] and are commonly used as intervention mechanisms [**16**,**17**,**18**,**19**,**20**]. Studies have reported that health promotion apps based on behavioral change techniques are more likely to be effective in eliciting changes in behaviors [**11**,**13**,**17**,**18**]. However, many of the current apps were developed without adopting such techniques [**12**]. Lack of expert participation in the design stage, evidence, and a theoretical base to support interventions has been cited as the main reason for poor uptake and

discontinued use of mobile health apps [**13**,**17**]. Apps designed with content that includes the opinions of clinicians, interventions developed in evidence-based practice, and internal drivers, such as motivations, tend to be more effective in facilitating behavioral change compared with those that were not [**13**,**18**].
A recent new tool for remote monitoring is Dental Monitoring**®** (DM, Paris, France), a software-based program that allows patients to capture their occlusion using a smart phone and a scan box. It consists of three integrated platforms: a mobile app for the user, a movement-tracking algorithm, and a web-based Doctor Dashboard®, where the clinician can check the treatment progress, teeth movement, integrity of appliances, and oral hygiene status through the analysis of pictures that are periodically taken by the patient [19]. Such remote monitoring is especially important in times of COVID-19 pandemic, as it allows maintaining continuity of care, while minimizing the risk of disease transmission and optimizing the use of resources [20].

To the best of our knowledge, the present work may be the first investigation of the oral hygiene status of orthodontic patients using the scan box. The aim of the study was to verify whether an active reminder—such as DM—integrated to the traditional periodontal standard of care, could help patients in maintaining a better oral hygiene during the first six months of treatment, and in reducing the number of appointments due to emergency reasons.

Methods

Study subjects

- Setting a clinically significant difference of 0.5 points in the Plaque Index (PI) between the two groups, a Standard Deviation (SD) of 0.5 ,a significance level α = 0.05, and a power beta = 80 %, the required sample size was calculated as 17 subjects for each group . Considering the drop-out rate, forty consecutive patients scheduled to start periodontal treatment between January and December 2022 were proposed to participate in the study. Inclusion criteria were to be online daily, to have access to a smartphone, and to undergo a periodontal therapy. Exclusion criteria were patients received periodontal treatment within 3 months ; Patient has disease related to periodontal disease (ex. Drug-related excessive gum growth or blood clotting problems, pregnancy, mental illness) and Disability patients

Participants with periodontitis were recruited and randomly assigned to an DM monitoring Group (DM; n = 20), and control (CG; n = 20) group. All participants received non-surgical periodontal treatment. We employed an AI-assisted tool called DENTAL MONITORING® (DM) intervention, a new technological AI monitoring product that utilizes smartphone cameras for intra-oral scanning and assessment. Patients in both the groups received additional real-person counselling over 3 months and the parameters were assessed at baseline ,2 weeks and 2 months.
Measurements
The recorded clinical parametres include:

Plaque Index (PLI): By utilizing the plaque index

Gingival index (GI): By using gingival index

Bleeding on probing (BoP): By using a Williams periodontal probe and passing it to the base of the probable pocket (Gingival Sulcus Bleeding Index) for four surfaces of all teeth , in BOP score "I" is given in case of bleeding emerges within 15 seconds after probing (the presence of bleeding and score "0" for the absence of bleeding.

Probing pocket depth (PPD): Williams periodontal probe was used to measure the distance in millimeters between the gingival margin, the base of the gingival sulcus, or pocket at four surfaces of each tooth.

Method of measurement of clinical attachment level (CAL)

The distance between the cemento-enamel junction (CEJ) and the base of the pocket can be measured to the closest millimeter with a Williams graduated periodontal probe.

Statistical Analysis

Statistical analyses of the entire data were performed using SPSS 16 software program. The mean values and standard deviation values for each parameter included were calculated using analysis of variance. Intergroup comparison and intragroup comparison were done using paired t-test and unpaired t-test, respectively. P values from all statistical tests were presented, but were considered statistically significant at $P \leq 0.05$ and highly significant at $P \leq 0.001$.

Result

I. Intergroup comparison

1. Plaque index

On comparing the mean values for Group I and Group II, Group I and Group III, and Group II and Group III, PI at 2 weeks and 3 months from baseline was found to be insignificant [Table 1].

Table 1

Comparison of mean values of plaque index between Group I and Group II, at baseline, 2 weeks, and 3 months (original)

Plaque index	Group I Mean±SD	Group II Mean±SD	*P*
Baseline	2.14±0.34	2.43±0.35	0.076
2 Weeks	1.23±0.07	1.38±0.15	0.012*

3 Months	1.11±0.09	1.04±0.10	0.011*

SD: standard deviation. *Significant ($P \leq 0.05$)

Graph 1

Intergroup comparison of mean plaque index, gingival index, pocket probing depth, and clinical attachment level at baseline, after 2 weeks, and after 3 months between all three groups (original)

2. Gingival index

On comparing the mean values for Group I and Group II, GI at 2 weeks was found to be highly significant and more in Group II when compared with Group I and also at baseline and 3 months GI was found to be significant. [Table 2].

Table 2

Comparison of mean values of gingival index between Group I and Group II, Group I and Group III, and Group II and Group III at baseline, 2 weeks, and 3 months (original)

Gingival index	**Group I Mean±SD**	**Group II Mean±SD**	***P***
Baseline	2.21±0.36	2.41±0.41	0.263
2 Weeks	1.19±0.10	1.36±0.09	0.001*
3 Months	1.02±0.10	1.02±0.15	0.039*

SD: standard deviation. *Highly significant ($P \leq 0.001$). †Significant ($P \leq 0.05$)

3. Pocket probing depth

On comparing the mean values for Group I and Group II, PPD after 2 weeks was found to be significantly more in Group II ($P = 0.008$), and also at baseline and 3 months PPD was found to be significant. [Table 3].

Table 3

Comparison of mean values of pocket probing depth in Group I and Group II, Group I and Group III, and Group II and Group III at baseline, 2 weeks, and 3 months (original)

Pocket probing depth	**Group I Mean±SD**	**Group II Mean±SD**	***P***

Baseline	5.85±0.42	6.29±0.79	0.138
2 Weeks	4.92±0.59	5.70±0.58	0.008*
3 Months	4.13±0.61	4.28±0.47	0.044*

SD: standard deviation. *Significant (*P*≤0.05)

4. Clinical attachment level

On comparing the mean values for Group I and Group II, CAL at 2 weeks was found to be significantly more in Group II (*P* = 0.017), and also at baseline and 3 months CAL was found to be significant. [Table 4].

Table 4

Comparison of mean values of clinical attachment level in Group I and Group II, Group I and Group II, I and Group II and Group III at baseline, 2 weeks, and 3 months (original)

Clinical attachment level	Group I >Mean±SD	Group II >Mean±SD	*P*
Baseline	6.49±0.85	7.47±1.23	0.054
2 Weeks	5.88±0.70	6.83±0.90	0.017*
3 Months	5.15±1.03	5.61±0.95	0.307

SD: standard deviation. *Significant (*P*≤0.05)

II. Intragroup comparison

In this category, the comparison of values for each parameter was done within every group. The mean value of each parameter was compared between baseline and 2 weeks, baseline and 3 months, and 2 weeks and 3 months.

1. Plaque index

On intragroup comparison, the mean difference values of PI when compared after 2 weeks from baseline and after 3 months from baseline for Group I and Group II were found to be highly significant [Table 5].

Table 5

Intragroup comparison of plaque index after 2 weeks and 3 months from baseline in Group I, Group II, and Group III

Plaque index	**Group I**		**Group II**	
	Mean±SD	***P***	**Mean±SD**	***P***
Baseline and 2 weeks	0.91±0.38	0.00†	1.05±0.31	0.00†
Baseline and 3 months	1.02±0.39	0.00†	1.38±0.39	0.00†
2 Weeks and 3 months	0.11±0.09	0.00†	0.34±0.22	0.00†

SD: standard deviation. †Highly significant

Graph 2

Intragroup comparison of mean difference in plaque index, gingival index, pocket probing depth, and clinical attachment level from baseline to 2 weeks, baseline to 3 months, and 2 weeks to 3 months in all three groups (original)

2. Gingival index

On intragroup comparison, the mean difference values of GI when compared after 2 weeks and 3 months from baseline for Group I and Group II, were found to be highly significant (*P* = 0.00). When compared after 3 months from 2 weeks' values of GI for Group I and Group II, and the values were found to be highly significant (*P* = 0.00)

Table 6

Intragroup comparison of gingival index after 2 weeks and 3 months from baseline in Group I, Group II, and Group III

Gingival index	**Group I**		**Group II**	
	Mean±SD	***P***	**Mean±SD**	***P***
Baseline and 2 weeks	1.02±0.36	0.00†	1.05±0.42	0.00†
Baseline and 3 months	1.19±0.35	0.00†	1.39±0.34	0.00†
2 Weeks and 3 months	0.17±0.14	0.00†	0.34±0.16	0.00†

SD: standard deviation. †Highly significant ($P \leq 0.001$). *Significant ($P \leq 0.05$)

3. Pocket probing depth

On intragroup comparison, the mean difference values of PPD when compared after 2 weeks from baseline, and 3 months from baseline between 2 weeks and 3 months for Group I and Group II and were found to be highly significant [Table 7].

Table 7

Intragroup comparison of pocket probing depth after 2 weeks and 3 months from baseline in Group I, Group II, and Group III

Pocket probing depth	**Group I**		**Group II**	
	Mean±SD	***P***	**Mean±SD**	***P***
Baseline and 2 weeks	0.93±0.78	0.00†	0.60±0.26	0.00†
Baseline and 3 months	1.72±0.85	0.00†	2.01±0.62	0.00†
2 Weeks and 3 months	0.79±0.63	0.00†	1.41±0.39	0.00†

SD: standard deviation. †Highly significant ($P \leq 0.001$)

4. Clinical attachment level

On intragroup comparison, mean difference values of CAL for Group I and Group II when compared after 2 weeks and 3 months from baseline were found to be highly significant (P = 0.00). [Table 8].

Table 8

Intragroup comparison of clinical attachment level after 2 weeks and 3 months from baseline in Group I, Group II, and Group III

Clinical attachment level	**Group I**		**Group II**	
	Mean±SD	***P***	**Mean±SD**	***P***
Baseline and 2 weeks	0.61±0.33	0.00†	0.64±0.46	0.00†
Baseline and 3 months	1.35±0.91	0.00†	1.86±0.53	0.00†
2 Weeks and 3 months	0.74±0.79	0.01*	1.22±0.30	0.00†

SD: standard deviation. †Highly significant ($P \leq 0.001$). *Significant ($P \leq 0.05$)

Discussion

DM is an orthodontic application that can be used for remote monitoring. It combines teledentistry and artificial intelligence (AI) using a knowledge-based algorithm, allowing an accurate semi-automated monitoring of orthodontic treatment [21]. Through DM, dentists can remotely monitor tooth movement, orthodontic devices integrity, and patient's oral hygiene [22].

The present study focused on the monitoring of periodontal patients, and the record of PI, originally described by Silness and Loe [23], was one of the parameters selected to evaluate the level of their oral hygiene status. In the literature, the PI was used in the majority of the trials [24], as it allows a rapid assessment and it is workable in dental offices without expensive costs. According to best clinical practice principles, plaque assessment further included the use of disclosing-plaque tablets, which evidence was photographed and shown to patients and parents in order to enhance collaboration and oral hygiene independently from the use of remote digital monitoring. In fact, it is an affordable and easy-to-perform visual method that provides a rapid feedback to improve brushing technique and conscious awareness [25].

With regard to PI, the control group showed a worsening of the oral hygiene level, although after three months the accumulation of plaque substantially decreased. This might be interpreted as a sign that instructions and visual method of disclosing-plaque tablets eventually enhanced awareness in patients and families on the importance of a good oral hygiene [25].

With regard to GI, the control group showed a worsening of the periodontal health status during the first months of treatment, according to the literature [24,25]. Conversely, in the study group, the GI dropped by more than half of the initial values by the end of the observation period. However, the difference between the two groups was significant and it is unclear whether DM also helped to improve the periodontal status.

A relevant finding was the difference in terms of PPD and CAL between the two groups, where DM is likely to have played an important role in enhancing the attention of the patients on oral hygiene control. Still, the overall improvement in oral hygiene of the study group might be partly due to the Hawthorne Effect [26], as patients in the study group were aware of being under monitoring by the examiner.

The study conducted by Shen KL et al 2022[27] reported greater improvement in probing pocket depth (PPD) (mean diff = -0.9 ± 0.4 and -1.4 ± 0.3, clinical attachment level (mean diff = -0.8 ± 0.3 and -1.4 ± 0.3,), and plaque index (mean diff = -0.5 ± 0.2 and - 0.7 ± 0.2) at 3-month follow-up by Dental monitoring Group than the control group did.

Also, a Research conducted by Sangalli et al. proved that DM is effective in reducing plaque index (PI) in orthodontic patients .[28]

Such remote digital technologies may include potential concerns, including a possible deterioration in patient-clinician relationship due to a reduced number of in-person appointments, and the inevitable cost of using AIRM itself [29]. Considering the novelty of such technological advances and the lack of well-defined standards [30], the clinicians should carefully balance the benefits of in-office visits with the advantages of remote monitoring, while maintaining standard of care.

Limitations

The value of GI was significantly different at baseline between study group and control group, and randomized studies are necessary to confirm the present findings. Further works may also extend the observation period to one year, in order to complete the orthodontic treatment, or longer, to observe the retention period as well. In the present study, patients used DM dedicated cheek retractors when taking the scans. However, every person is unique in the amount of maximal mouth opening and cheek muscle tonicity, which may have affected the tooth visibility in the oral cavity. Also how well teeth are captured may vary depending on the manual skills of each individual, and such variation may have influenced the present results.

Conclusions

Remote monitoring applied during periodontal treatment showed encouraging results in reducing plaque and periodontal variables. However, incidence of emergency appointments, gingival status, and onset of white spot lesions may not significantly improve. These preliminary results suggest potential application of this technology in clinical practice, especially in times when routine clinical check-ups might be compromised. Further randomised studies including larger and more homogeneous groups of participants are advisable to confirm the present findings.

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