Exploring mobile applications for oral health promotion: a randomized clinical trial

Joana Fonseca Costa*, MSc(DH); **Sónia Mendes**[§], PhD

*PhD student, Universidade de Lisboa, Faculdade de Medicina Dentária, Lisbon, Portugal

§Professor of Community and Preventive Dentistry, Universidade de Lisboa, Faculdade de Medicina Dentária, Lisbon, Portugal

Corresponding author: Joana Fonseca Costa
Universidade de Lisboa
Faculdade de Medicina Dentária
Lisbon, Portugal
Unidade de Investigação e Ciências Orais e Biomédicas (UICOB)
Cidade Universitária, R. Professora Teresa Ambrósio, 1600-277 Lisboa
Email: joanac@edu.ulisboa.pt

ABSTRACT

Background: This study explored young adults' perceptions of oral health apps and assessed whether the *Dentalcluj Brush Assistant* or *Brush DJ* apps improve oral hygiene and gingival inflammation. **Materials and Methods**: An exploratory randomized clinical trial with a parallel design conducted among Bachelor in Dental Laboratory Technology students. Inclusion criteria required students to be between 18 and 20, have a smartphone, and sign the informed consent. Participants received a dental hygiene appointment at baseline, followed by simple random and sequential allocation into one of three groups: *Brush DJ* app, *Dentalcluj Brush Assistant* app, or control group. App users were instructed to download and use the app during the study. Data collection included questionnaires and intraoral examinations. Questionnaires assessed oral hygiene behaviors and app perceptions at baseline and after the study. A calibrated and blinded investigator measured the Bleeding on Probing (BOP) Index and Simplified Oral Hygiene Index (OHI-S) at three moments, 15 days apart. Statistical analyses included Kruskall-Wallis, Mann-Whitney, Wilcoxon, and Friedman tests (α=0.05). **Results**: The sample comprised 24 participants (8 per group). All groups improved OHI-S index, but the *Dentalcluj Brush Assistant* group showed the most significant results (p=0.004) and was the only group with significant BOP index improvement (p=0.02). Half the participants found the apps helpful, highlighting the visual step-by-step brushing technique. However, some noted issues with impracticality and aesthetics. **Conclusions**: Apps appear beneficial as a complement to oral health appointments, with the *Dentalcluj Brush Assistant* showing the best results.

Keywords: mobile health; oral health; oral hygiene; toothbrushing; young adults

CDHA Research Agenda category: access to care and unmet needs

INTRODUCTION

Oral diseases continue to be a worldwide scourge and entail a considerable social and economic burden due to their high prevalence, being considered a public health problem.[1,2] Despite their prevalence, dental caries and periodontal disease can be prevented by controlling the oral biofilm,[3,4] with twice-daily toothbrushing[5,6] with fluoridated toothpaste being recommended.[6,7]

Oral biofilm control requires a daily self-care routine, which can be difficult to adhering and maintain over time.[1] One of the primary roles of the dental hygienist is to motivate and provide the necessary instructions for correct biofilm removal, and it is essential to reinforce this regularly. Since there is still a low frequency of regular visits to oral health professionals in the Portuguese population[8], technology could complement the oral health appointment, reminding the patient of the instructions given and motivation to do it more regularly and over time.

The last few decades have seen an intense technological revolution, with technology increasingly influencing people's routines, especially in young adults.[9] Accompanying this technological growth, the health sector started to use technology and mobile applications (apps) to improve and maintain healthcare, an aspect referred to as Mobile Health or MHealth.[10,11] The World Health Organization (WHO) defines MHealth as a medical and public health practice supported by mobile devices such as cell phones, patient monitoring devices, personal digital assistants, and other wireless devices.[11] The use of apps can be an innovative way of improving healthcare. It can promote closer and faster communication with the healthcare professional and allows individuals to quickly monitor their health through access to helpful information anytime and anywhere.[12]

There has also been a growing use of technology to promote oral health, with several apps that aim to help the routines of patients and oral health professionals.[13] Most of these are created to improve toothbrushing, using reminders for twice-daily toothbrushing and instructions on the

technique to adopt.[8,14] Some contain information on complementary oral hygiene aids (such as flossing and fluoride)[9,14] or information about oral health appointment frequency.[14] There are also gamified oral health apps[15-17] and apps from specific brands linked via Bluetooth to electric toothbrushes, which allows more accurate and monitored toothbrushing.[14]

The use of apps in oral health is increasing among patients, especially younger ones, and it has the potential to improve oral hygiene, knowledge, and behaviors, but more studies are needed.[18,19] Some studies revealed that the use of digital devices, which provide reminders and toothbrushing instructions visualized in real-time, can be effective in controlling biofilm and, consequently, in controlling gingival inflammation.[19-30]

In the Portuguese population, studies still need to evaluate this type of app's use, effectiveness, and acceptability. Therefore, this study aims to analyze if an app can motivate young Portuguese adults to do oral health self-care using two existing apps (*Brush DJ* and *DentalCluj Brush Assistant*). The specific objectives were: 1) To explore perceptions regarding the use of a mobile app as a supplementary tool for improving and maintaining oral health. 2) To evaluate the impact of using a mobile app, in conjunction with dental hygiene appointments, on gingival inflammation, oral hygiene levels, and motivation for oral health self-care.

MATERIALS AND METHODS

This study was approved by the Health Ethics Committee of the Faculdade de Medicina Dentária da Universidade de Lisboa (FMDUL) (ref: CE-FMDUL202160) and followed the CONSORT statement for randomized clinical trials[31], except for the clinical trial registration.

An exhaustive search was carried out on both Playstores (Google and Apple) to identify free apps that were easy to use and matched the objectives of this study. To ensure a meaningful comparison, two apps with distinct functionalities were intentionally chosen: Brush DJ (a

widely used app that provides only a timer with music for toothbrushing, without visual guidance, available on both Apple Store and Google Play Store) and DentalCluj Brush Assistant (an app offering guided toothbrushing with visual support, available until 2023 exclusively on Google Play Store). This selection allowed us to assess potential differences in effectiveness between a simple timer-based approach and a guided brushing experience. These apps were chosen after a review of the available apps and which had the following characteristics reminders for toothbrushing, information on oral disease prevention, brushing guidance through images, timers, and/or text, being free of charge, available in Portuguese or English, and easy to install on mobile devices. Additionally, the selection criteria included a focus on young adults and the absence of any association with a specific toothbrush or brand.

The study was a single-blinded randomized clinical trial with a parallel design and a ratio allocation of 1:1:1. It included two experimental groups (A and B) and a control group (C). The experimental groups were exposed to each of the two selected apps (depending on the smartphone used, whether iOS or Android), while the control group was not exposed to any app. The experimental and control groups proceeded simultaneously and independently throughout the research.

A non-probabilistic sample included FMDUL students from the first and second years of the Bachelor in Dental Laboratory Technology. A minimum of 8 participants per group was considered. This value was calculated with an online application (https://epitools.ausvet.com.au/) using the following parameters: significance level of 0.05, power of 0.80, and difference between means of 3. The outcome used to generate the sample size calculation was the Simplified Oral Hygiene Index (OHI-S).

Participants were selected based on previously defined inclusion and exclusion criteria. Students who owned a smartphone were between 18 and 20 years old and signed the informed consent form were included in the study. Exclusion criteria were the use of an electric

toothbrush, the previous use of an app for oral health self-care, not having basic knowledge of English, or having a systemic disease that affects oral health.

Data was collected using an initial questionnaire, a final questionnaire, and three intraoral examinations during the study. Two dental hygienists with experience in questionnaire research reviewed the questionnaires to check the relevance and content of the questions. A pre-test was conducted with six young individuals aged 18 to 20, and necessary adjustments were made based on their feedback.

Data collection was made between February and April 2023 and included the following phases, which will be described in detail below: 1) Selection of the participants; 2) Baseline examination and dental hygiene appointment; 3) Intermediate examination; 4) Final examination.

Selection of the participants

Participants were selected on the dental school premises at the start of a lesson. Students who agreed to participate signed the informed consent and completed the initial questionnaire. This questionnaire collected sociodemographic information, relevant health problems, the operating system of the participant's smartphone, oral health perception, and oral health behaviors. At this moment, a dental hygiene appointment was also scheduled.

An individual identification number was created for each participant to permit simple randomization and the matching between the three study moments.

Baseline examination and dental hygiene appointment

The baseline examination was performed using a WHO CPI probe and an oral dental mirror[32], and the dental hygiene appointment was made at the university clinic. The examination included registering the DMFt index according to the WHO criteria[32], the Simplified Oral Hygiene Index (OHI-S)[33], and the Bleeding on Probing Index (BOP).[34] No dye was used to record the OHI-S Index, and only the CPI probe was used to assess the soft deposit component. A previously trained and calibrated examinator (dental hygienist) measured all the indices.

After the index's registration, the same investigator made a dental hygiene appointment for all the participants, which included calculus removal with ultrasound, polishing, and self-care instruction, considering a previously established script (demonstration of toothbrushing by the modified Bass method and the importance of flossing, this late mentioned but not demonstrated).

After the appointment, a second team member accompanied the participant to another clinic room for the simple random allocation of the study groups, as the examiner was blind to this allocation. Each of the 24 participants, previously selected and meeting the inclusion and exclusion criteria described above, were numbered and listed, and then a simple random and sequential choice (A - *DentalCluj Brush Assistant*; B - *Brush DJ*; C - Control) was made for each of the groups, thus allowing all groups to have an equal number of participants. The randomization was assisted by the app *Research Randomizer* (https://www.randomizer.org/).

Participants allocated to the experimental groups were asked to download the app, and a brief explanation about the app's features was given using a previously established script with clarifying images. These participants were requested to use the app during the study and record their use and toothbrushing in a calendar provided by the research team's registrar. The control group participants received no app but the calendar to record toothbrushing. All participants were instructed to keep their usual toothbrush and toothpaste. This provision and allocation was made by a member of the research team who recorded the data and who did not collect the

indices in order to make this examiner blind to the exposure (use of the app or not). The only difference between the groups was the use of the app to promote oral self-care after the appointment.

Intermediate examination

The intermediate clinical examination was conducted 15 days after the initial one in the same environment conditions. The OHI-S and BOP indices were recorded in this examination under the same conditions described above for baseline examination. The same blind examiner performed all procedures, and the participants were previously instructed not to mention the group they had been allocated to.

Final examination

The final examination was made 15 days after the intermediate and included the same procedures and conditions. After the final examination, participants were asked to return the toothbrushing and app frequency calendars and respond to the final questionnaire. The latter collected information about oral hygiene behaviors and, in the experimental groups, the opinion about the app used. The flow diagram, according to the CONSORT guidelines, is presented in Figure 1.

Data analysis

Data was analyzed using the Statistical Package for Social Sciences, version 27 (SPSS® 27.0). Absolute and relative frequencies of the variables were calculated, as well as the mean and standard deviation (sd) for numerical variables. The Kruskal-Wallis, Wilcoxon, Friedman, and Mann-Whitney tests were used (α=0.05). The Kruskal-Wallis test was used to assess differences between the three independent groups of the study regarding DMFT, OHI-S, and BOP (at baseline and the end of the study). The Wilcoxon test was applied to analyze differences between two conditions for paired samples, namely to assess the differences in the frequency

of toothbrushing and flossing between each group's baseline and final moments. The Friedman test was used for the three paired conditions to assess differences in the OHI-S and BOP, comparing the three moments (baseline, intermediate, and final examinations). Finally, the Mann-Whitney test was used to compare differences between the two groups of app users about the number of times the app was used during the total of weeks of the study.

RESULTS

The study sample included all 24 previously recruited individuals, equally and randomly distributed into the three study groups. No exclusions occurred after randomization. The mean age of the participants was 18.5 years (sd = 0.51). Table 1 describes the characterization of the sample.

When the frequency of toothbrushing and flossing was compared between the baseline and final moments of the study, there were no significant differences in any of the groups ($p > 0.05$) (Table 2).

The groups were compared using baseline records, considering each oral health index. The baseline mean DMFT was 3.67 (sd = 3.17), and no significant differences were found between the groups ($p > 0.05$). The component that most contributed to the DMFT was filled teeth (88.6%), with a few untreated dental caries (6.8%) and missing teeth (4.6%). There were also no significant differences at baseline regarding the OHI-S ($p>0.05$). However, the BOP index showed a better percentage in the *Brush DJ* group compared to the *Dentalcluj Brush Assistant* group ($p = 0.007$) and the control group ($p = 0.03$).

Comparing the groups over the three examination moments, all groups showed a tendency, not always significant, to improve the oral health indices during the study. There were significant differences in the control group ($p = 0.02$) and the *Dentalcluj Brush Assistant* group ($p=0.004$)

regarding the OHI-S index. For the BOP index, there were only significant differences in the *Dentalcluj Brush Assistant* group (p = 0.02). The differences were always between the baseline and final moments (Table 3).

According to the calendars given by the participants, the mean number of times they used the app was 15.1 (sd = 15.3), considering the total weeks of the study. There was a general descending trend in using both apps, but it was less evident in the *Dentalcluj Brush Assistant* group. The mean number of times was higher in the *Dentalcluj Brush Assistant* group (18.3±15.1) than in the *Brush DJ* group (11.4±15.8) but with no significant differences (p = 0.12) (Table 4).

Half of the participants in the experimental groups found the app useful (75% in the *DentalCluj Brush Assistant* group and 25% in the *Brush DJ* group). The app most often used, most recommended, and most likely to be used in the future was the *Dentalcluj Brush Assistant* (Table 5).

The participants highlighted both positive and negative aspects of using the apps. The most positive elements mentioned were "the support in brushing technique because it is demonstrated visually" and the "timer." The timer was mentioned in both mobile apps, while the help with brushing technique was often mentioned in the *Dentalcluj Brush Assistant* group. The most negative aspects indicated in both apps were: "Not practical", "Wasting more time", and "Having to take the phone to the toilet." In the *Dentalcluj Brush Assistant* group, the aesthetics/design, "Not being in the Portuguese language", and "After using two or three times, it becomes memorized" were also mentioned as negative aspects. The *Brush DJ* group participants also indicated: "It has few songs associated with it" and "After the first time, it may no longer be necessary to continue using it."

DISCUSSION

Apps can have features that promote better oral health and that motivate more positive behaviors, such as accompanying patients in their daily routines and providing information through images and demonstrations.[20,22,35] They can also be helpful for oral health professionals, creating a closer relationship with the patient.[36]

However, the effectiveness of apps in improving oral health indices is contradictory. Some studies show improvement in the experimental groups, while others show no differences between the experimental and control groups.

A 3-months study found that the behaviors and attitudes of high school students when they experienced one of two forms of oral health education (*Brush DJ* app or conventional oral health education sessions) were similar.[35] In the present study, the *Dentalcluj Brush Assistant* group had two participants who reported starting to use dental floss, and a third reported using it more frequently. Although these differences were not significant, these results should be considered, as this app seems to impact the motivation for oral health self-care, particularly in flossing.

No significant differences existed between the baseline and final moments regarding the OHI-S and BOP indices in the Brush DJ group. Another study, which investigated the effect of the same app for 12 weeks on adolescent orthodontic patients, found significant improvements in the experimental group's plaque and gingival indices. Also, in the same study, the frequency of app use was positively correlated with the frequency and duration of toothbrushing.[24]

In the *Dentalcluj Brush Assistant* experimental group and the control group, oral hygiene (OHI-S) improved significantly from the baseline to the final moment. The improvement was much more evident in the experimental group, which could highlight the potential of using an app to

complement a routine oral health appointment and to reinforce the dental hygienist's instructions.

The potential of using an app to improve oral health indicators is also reinforced by improving the gingival inflammation (BOP index) in the *Dentalcluj Brush Assistant* group, the only group to record significant differences between the baseline and final examinations in this index. This result is supported by a literature review that indicated a significant reduction in biofilm in experimental app groups compared to control groups.[23]

Although no significant differences were found in the *Brush DJ* experimental group oral health indices, this group started the study with a lower BOP index when compared to the other groups, which may have affected the results, as it is more challenging to improve the gingival inflammation in this experimental group. The group tended to improve the gingival inflammation, but not significantly, although the p-value was close to the statistical decision limit (p=0.08). Unlike the other experimental group, the OHI-S index did not improve significantly in this *Brush DJ group*. The better results of the *Dentalcluj Brush Assistant* group could be related to the characteristics and features of the app. This app does not just have a timer, like *Brush DJ*; it offers other features considered positive by the participants, namely the visual monitoring of toothbrushing step-by-step, which can motivate the patient to improve the technique and consequently improve oral health indices.

The literature shows that verbal information accompanied by written messages, images, and demonstrations has better results in changing risk behaviors for oral health.[37] In fact, modeling behaviors through video has shown potential benefits in clinical practice, facilitating the acquisition of knowledge and improving self-care.[38] This improvement supports the theory of self-efficacy, created by Bandura in 1977[39], that states that behavior can be changed by an individual's beliefs in their abilities to control the events that affect their routines.[39] The use of

mHealth apps can be a suitable method for improving individuals' self-efficacy, particularly in more time-consuming and technical procedures, such as toothbrushing and flossing regularly.

Some other studies that have analyzed the impact of apps with this step-by-step toothbrushing functionality, similar to *Dentalcluj Brush Assistant*, concluded that their use contributed to improving oral health indicators.[20,29]

Despite the positive and promising results for the *Dentalcluj Brush Assistant* experimental group, there were also significant differences in the OHI-S index in the control group, indicating that using apps is not a substitute for direct communication between health professionals and patients.[35,40] The use of apps, especially those that reinforce oral hygiene techniques step-by-step, seem to be helpful, primarily if used as a complement to the dental hygiene appointment, motivating the patient and reinforcing the instructions over time and helping the oral health professional in the appointment, complementing their communication and eventually reducing the length of the appointment.

A study conducted in young Portuguese adults revealed that about 73% of the participants considered an app for oral health motivation helpful, although only 6.1% reported already using one.[41] In the present study, only 50% of the participants considered using these apps beneficial, and their frequency of use decreased over the weeks, especially in the *Brush DJ* group. Additionally, using an app can be discouraging over time because it becomes repetitive. Both the positive and negative aspects and the limitations pointed out by participants can justify the frequency of use of the app and its recommendation. The literature highlights various features valued by users of oral health apps, such as providing information, timer, brushing record, sharing information with the health professional, being free, easy to use, and saving time.[9,12,41,42] The characteristics identified that most pleased and displeased the participants should be considered when choosing an app to advise a patient and developing new oral health apps.

Although this study had a small convenience sample, which limits the extrapolating of the results, it could serve as an exploratory study into young people's perceptions of using oral health apps in the Portuguese population. As a non-probabilistic sample, the study included students with less contact with oral disease prevention, no clinic and patient training, and at the beginning of their academic training. More studies are necessary, but apps related to oral health promotion seem to be a valuable and appealing tool for improving the population's health indicators. Oral health professionals can use these technologies to promote their patients' oral health, making their demonstrations more appealing and facilitating the communication process with the patient.

CONCLUSION

Using an app with a step-by-step toothbrushing technique, like DentalCluj, can significantly improve oral hygiene levels and gingival inflammation. A considerable number of the participants considered it helpful to use an app to support their oral health self-care. The most positive aspects highlighted were the brushing monitoring (with a step-by-step toothbrushing technique), the information on oral diseases, the oral health appointment reminders, and the toothbrushing timer.

The results of this study confirmed that an app can be a valuable tool for supporting the oral hygiene of young adults as a complement to an oral health appointment. The features mentioned by the participants may be important to consider when choosing an app to advise patients and developing new apps to improve oral health self-care.

ACKNOWLEDGEMENTS

The authors thank all the study participants for their time and support.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

FUNDING

The authors received no financial support for this article's research, authorship, and/or publication.

AUTHOR DISCLOSURE STATEMENTS

The authors declare that they have no relevant financial or material interests related to the research described in this article.

DISCLOSURE OF AI-GENERATED CONTENT

To prepare this manuscript, the authors used the app Grammarly to help with the manuscript translation and writing quality. Before adding the translation to the submission, the authors reviewed and corrected it, as required, and took full responsibility for its content.

PRACTICE IMPLICATIONS / RELEVANCE

1. An app can be a valuable and appealing tool for complementing and motivating some patients to practice oral self-care and improve the population's health indicators.
2. Apps with toothbrushing monitoring and a step-by-step technique can have better results regarding oral health indicators.

3. Oral health professionals can use these technologies to promote their patients' oral health and facilitate communication.

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TABLES

Table 1. Characterization of the sample according to sociodemographic characteristics, oral health perception, and oral health appointments (n=24).

		%	n
Sex	Female	75.0	18
	Male	25.0	6
Age	18 years-old	50.0	12
	19 years-old	50.0	12
Oral health perception	Very bad	0.0	0
	Bad	4.2	1
	Reasonable	29.2	7
	Good	54.2	13
	Very good	12.5	3
Frequency of oral health appointments	Never	0.0	0
	Less than a year	12.5	3
	Once a year	58.3	14
	Twice a year or more	29.2	7
Reason for last dental appointment	Routine	33.3	8
	Dental treatment	20.8	5
	Pain	16.7	4
	Oral hygiene	16.7	4
	Tooth extraction	4.2	1
	Orthodontics	4.2	1
	Don´t remember	4.2	1

Table 2. Comparison of oral hygiene behaviors between the baseline and final moments of the study.

		Control			***Dentalcluj Brush Assistant***			***Brush DJ***		
		baseline	**final**	***p****	**baseline**	**final**	***p****	**baseline**	**final**	***p****
		% (n)			% (n)			% (n)		
Toothbrushing	**Daily**	25.0 (2)	25.0 (2)	1.0	12.5 (1)	12.5 (1)	1.0	0.0	0.0	1.0
	Twice/day	75.0 (6)	75.0 (6		87.5 (7)	87.5 (7)		100 (8)	100 (8)	
Flossing	**Do not use**	25.0 (2)	25.0 (2)	1.0	50.0 (4)	25.0 (2)	0.2	12.5(1)	12.5 (1)	1.0
	Less than one per week	0.0	0.0		0.0	12.5 (1)		0.0	12.5 (1)	
	Once/week	50.0 (4)	50.0 (4)		37.5 (3)	37.5 (3)		62.5 (5)	62.5 (5)	
	Once/day	25.0 (2)	25.0 (2)		12.5 (1)	25.0 (2)		25.0 (2)	25.0 (2)	

*Wilcoxon test.

Table 3. Comparison by group of OHI-S and BOP between the study's baseline, intermediate, and final moments.

		Control	*p**	*Dentalcluj Brush Assistant*	*p**	*Brush DJ*	*p**
OHI-S	**Baseline**	0.83 [a]	**0.02**	1.04 [a]	**0.004**	0.73	0.08
	Intermediate	0.50 [ab]		0.71 [ab]		0.42	
	Final	0.38 [b]		0.50 [b]		0.38	
BOP	**Baseline**	34.0%	0.22	38.7% [a]	**0.02**	18.1%	0.28
	Intermediate	27.1%		29.0% [ab]		20.8%	
	Final	26.2%		26.5% [b]		15.4%	

*Friedman test with multiple comparisons.
The p-values in bold show statistically significant differences ($p<0.05$).
Values that share the same letter do not have statistically significant differences.

Table 4. Mean number of times the app was used during the weeks of the study.

	Week 1	Week 2	Week 3	Week 4	Total of the study	*p**
Dentalcluj Brush Assistant	5.29	4.75	4.38	4.50	18.25	0.12
Brush DJ	4.00	2.57	2.57	2.29	11.43	
Total	4.64	3.73	3.53	3.47	15.07	

*Mann-Whitney U-test.

Table 5. Participants' perceptions about the use of the apps.

		Dentalcluj Brush Assistant	*Brush DJ*	Total
		% (n)	% (n)	% (n)
Frequency of use	Never	0.0 (0)	12.5 (1)	6.3 (1)
	Rarely	12.5 (1)	50.0 (4)	31.3 (5)
	Frequently	50.0 (4)	25.0 (2)	37.5 (6)
	Often	37.5 (3)	12.5 (1)	25.0 (4)
Utility	Yes	75.0 (6)	25.0 (2)	50.0 (8)
	No	25.0 (2)	75.0 (6)	50.0 (8)
Reason the app is considered helpful	Motivated me to brush my teeth at least twice a day	0.0 (0)	0.0 (0)	0.0 (0)
	It taught me how to brush my teeth with the proper technique	75.0 (6)	37.5 (3)	56.3 (9)
	Helped me to brush my teeth for as long as necessary	75.0 (6)	37.5 (3)	56.3 (9)
	Other	33.3 (1)	0.0 (0)	33.3 (1)
Limitations	Yes	12.5 (1)	12.5 (1)	12.5 (2)
	No	87.5 (7)	87.5 (7)	87.5 (14)
Future use of the app	Yes	62.5 (5)	0.0 (0)	31.3 (5)
	No	37.5 (3)	100 (8)	68.8 (11)
App recommendation	1 – not recommend	0.0 (0)	28.6 (2)	13.3 (2)
	2	12.5 (1)	28.6 (2)	20.0 (3)
	3	25.0 (2)	28.6 (2)	26.7 (4)
	4	37.5 (3)	14.3 (1)	26.7 (4)
	5 – very likely to recommend	25.0 (2)	0.0 (0)	13.3 (2)

Figure 1. CONSORT flowchart

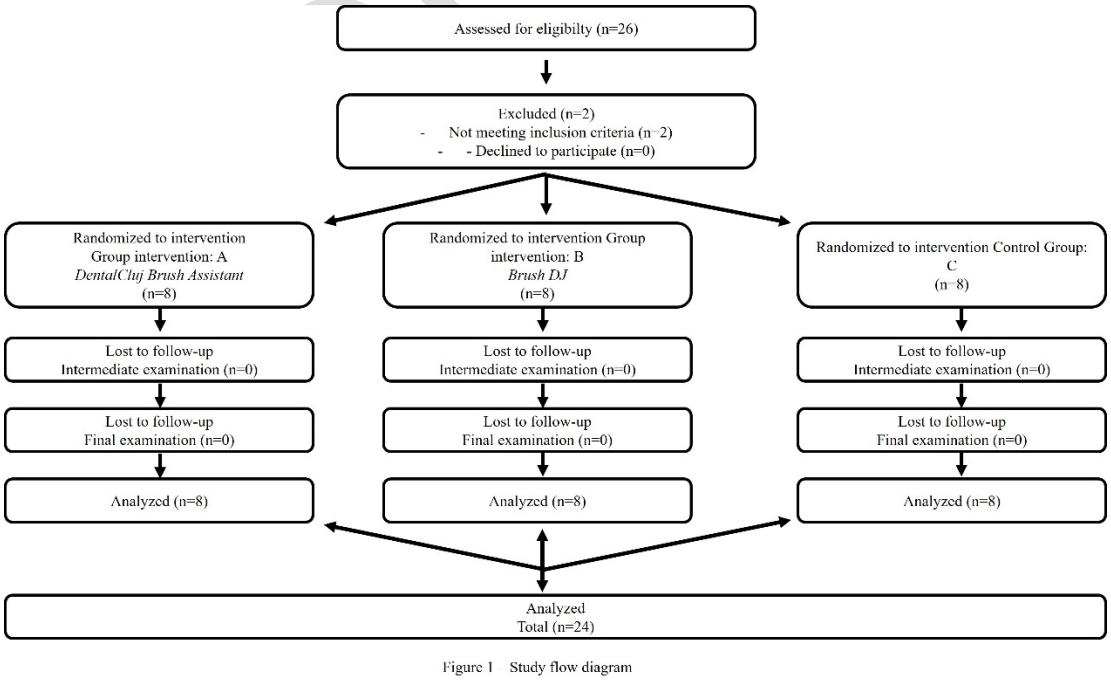

Figure 1 Study flow diagram