Toothbrushing compliance tracking in a nursing home setting using telemonitoring-enabled powered toothbrushes

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Key points

In a typical Danish public nursing home setting, toothbrushing levels were generally found to be suboptimal for the majority of the residents.

After introducing telemonitoring-enabled powered toothbrushes, plaque and bleeding scores improved significantly, but improvements were lost three months after the study.

It is relevant and practical to automatically measure the compliance level of daily toothbrushing activities in the nursing home setting using telemonitoring-enabled powered toothbrushes.

Abstract

Introduction Nursing home residents with cognitive and physical disabilities often depend on assistance from caregivers to perform personal hygiene tasks including toothbrushing. Only a minority receives the care needed and toothbrushing compliance levels are not registered.

Aims To describe toothbrushing compliance levels in a nursing home setting and investigate the relevance and practicality of using telemonitoring-enabled powered toothbrushes for automated compliance tracking. Furthermore, to investigate changes in plaque and bleeding scores.

Materials and methods Nursing home residents were provided with powered toothbrushes and telemonitoring gateways. Toothbrushing frequency and duration were automatically recorded by the telemonitoring gateways, and an email report was sent once a week to the nursing home manager. Plaque index and bleeding index were assessed by dentists at baseline, at the end of the intervention and at three months post-intervention.

Results Data from 20 participants for 100 days (3,920 measurements) were collected and used to evaluate toothbrushing compliance. A minority of toothbrushings (5%) were in compliance with the two-minute toothbrushing duration recommendation, while around 30% achieved the one-minute toothbrushing minimum duration recommendation. Around 25% of participants would get only one toothbrushing per day, while 40% would get none. Both plaque and bleeding scores improved significantly during the project, but all progress was lost three months after the project's end.

Conclusions It is relevant and practical to monitor toothbrushing compliance in the nursing home setting using telemonitoring-enabled powered toothbrushes. Despite finding limited compliance levels, a significant improvement in the plaque and bleeding index was found after the intervention, which was lost again three months after the telemonitoring gateways had been removed.

Introduction

Nursing home residents with cognitive and physical disabilities often depend on assistance from caregivers to perform personal hygiene tasks including daily oral care. A Swedish study found that 77% of the nursing home residents needed assistance with daily oral care activities including toothbrushing, but only 7% received the care needed.[1]

Oral care in nursing homes faces several obstacles due to the residents' disabilities and associated barriers including cooperation, communication and access. The oral care that is offered therefore needs to be customised to these barriers.[2]

In order to limit the level of oral diseases and subsequent tooth loss, plaque control and oral care need to be prioritised in the care of weak and frail elderly citizens.[3] Studies of tooth status and oral care hygiene levels among nursing home residents have shown an increased prevalence of untreated decay and periodontitis, as well as poor oral hygiene.[4] Also, it has been shown that these oral conditions affect the quality of life of the residents in terms of pain and discomfort.[5]

Besides oral health-related consequences, several studies propose an association between poor oral hygiene, periodontitis, and cardiovascular disease and diabetes.[6,7] Also, a recent evaluation of the literature suggests that optimal oral care may have a positive preventive effect on pneumonia in elderly citizens in hospitals and nursing homes.[8]

In the nursing home setting, assistance with daily oral care is part of basic nursing.

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However, studies have shown several barriers due to citizens', staff's and organisational constraints.[3]

The use of powered toothbrushes among the weak and frail elderly has previously been studied. Yaacob *et al.* in their review found that powered toothbrushes reduce plaque and gingivitis more than manual toothbrushing in the short and long term,[9] while other studies show the opposite effect.[10,11] However, in the nursing home setting, it is highly relevant to consider that the caregiving staff seem to prefer powered toothbrushes.[12]

McCracken *et al.* were the first to study the compliance level of oral care, specifically toothbrushing frequency and duration, using a data logger.[13] In their study, dental patients suffering from chronic periodontitis were given a powered toothbrush as part of the overall management of their periodontal disease. The toothbrush, a Philips Jordan Sensiflex 2000, was modified to carry a built-in data logger.[13] The study investigated toothbrushing compliance over two periods of two months each, having four months of no data collection in between. They found that about one-third of the participants were non-compliant with regards to the two minutes' toothbrushing duration.

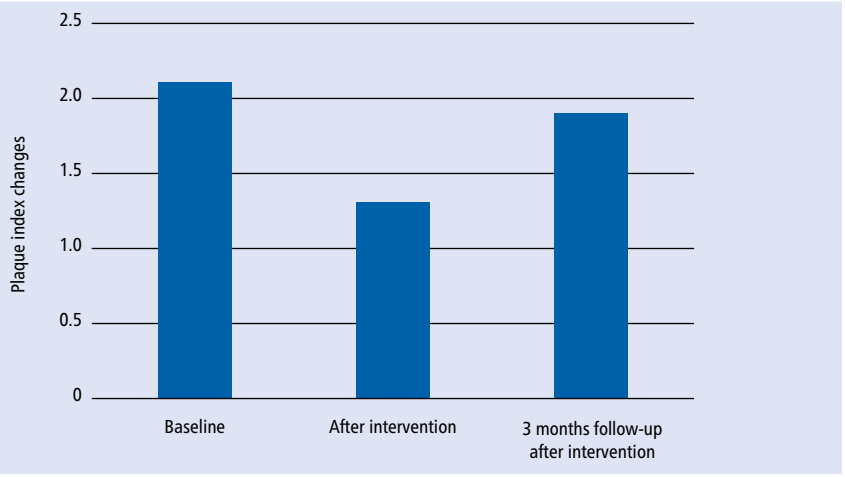
To the best of our knowledge, no studies have yet investigated oral care compliance in a nursing home setting, using automated data capture methods.

The aims of this study were: 1) to describe toothbrushing compliance levels in a nursing home setting; 2) to investigate the relevance and practicality of using telemonitoring-enabled powered toothbrushes for automated compliance tracking; and 3) to investigate the changes in plaque and bleeding scores of the participants.

Materials and methods

The study was planned as a descriptive observational trial, with participants recruited from a typical medium-sized nursing home in the capital region of Denmark. All residents who: 1) had more than six natural teeth with clinical crowns; 2) were already enrolled in the community nursing home dental service; 3) showed sufficient cooperation to participate in oral examination; and 4) were in need of some kind of assistance with daily oral care were invited to participate. The ability to cooperate in oral examination was assessed by each resident's usual dentist on the basis of experience from prior dental care history, and the need for assistance with daily oral care tasks was jointly assessed by participants' dentist and caregivers. No further selection or sampling procedure was performed.

Fig. 1 Mean plaque index at baseline, after the intervention and three months after the intervention at follow-up



The Regional Committees on Health Research Ethics for Southern Denmark testified before the project that the project did not fall within the scope of the Committee's Act and that approval by the Committee was therefore not needed. Written informed consent was obtained from all the invited residents or their closest relatives, if they were not able to give informed consent themselves. None of the 20 invited residents refrained from participation.

All participants received a free powered toothbrush of type Oral B Genius 9100 which would allow us to register frequency and duration of toothbrushing events. The Genius 9100 is equipped with a built-in radio communication module, allowing it to send usage data to a data logger gateway. In the study, the CARIOT telemonitoring gateway was used from Danish company Aliviate, Denmark. The CARIOT gateway would automatically record the toothbrushing frequency and duration data from the toothbrushes, and forward data to a central database with a timestamp and participant identification.

At baseline, the caregiving staff on the day and evening shifts as well as the residents were offered group lessons by a dentist and dental hygienist in the optimal handling of the device. On request and during the project, individual training in handling the device was delivered to the residents and caregivers by their usual dentist and dental hygienist.

The nursing home manager received a weekly email status and was encouraged to follow up on any missed toothbrushings. Thus, both management, caregiving staff and the participating nursing home residents were made aware of the monitoring.

At baseline, a clinical examination was carried out in the resident's private home. The examiner used a headlamp as a light source. A dentist (co-author CLD) made the clinical registrations, assisted by an experienced oral epidemiologist (co-author LBC) and, at the end of the project, also assisted by three dental hygienist students. In order not to further disturb and bother the participants, no clinical calibration was made; however, clear instructions and guidelines for registration procedures were thoroughly discussed among the examiners. The students' examinations and registrations were controlled and surveilled by LBC.

The following information was registered for each participant at baseline: age, sex, number of teeth, prostheses, plaque level and level of bleeding from the gums. Plaque was measured on the following six index teeth: 16, 26, 46, 36, 11 and 31, and was only measured on one site per tooth. For participants with reduced dentition, plaque was measured on either their index teeth or their neighbouring teeth. When plaque was clearly visible, it was registered with the value 3 (huge amounts of plaque covering most of the tooth) or with value 2, when less amounts of plaque were visible. A blunt probe was used for gentle probing of the orifice of the gingival crevice. With no visible plaque, but plaque found on the probe, the registration of the value was 1. No plaque was registered as 0. The plaque index was calculated by dividing the sum of scores by the number of registration sites, which will result in a value between 0 and 3.[14] Bleeding index was estimated with a single

Fig. 2 Mean bleeding index at baseline, after the intervention and three months after the intervention at follow-up

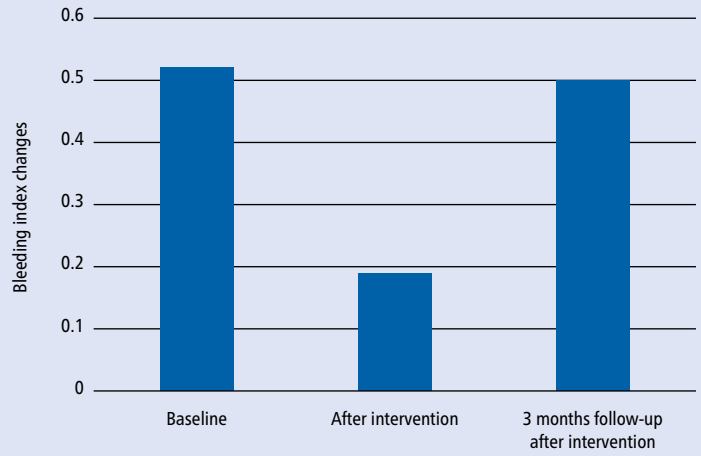


Table 1 Participant demographics

Characteristic	Data
Age (standard deviation)	82 (7.5)
Sex male/female	5/15
Average number of teeth (standard deviation)	18.6 (6.9)
Partial prostheses present	20%
Complete prostheses present	20%
Number of participants	20*

Key:
* = reduced to 19 participants after three months' project participation.

Table 2 Measured toothbrushing frequency and duration

Tooth brushing	Amount
Mean time used for toothbrushing in seconds (standard deviation)	66.5 (13.80)
Total toothbrushing time per citizen during 100 days in seconds	7,395
Mean number of days with two toothbrushing sessions per participant during 100 days* (standard deviation)	35.15 (25.58)
Mean number of days with one toothbrushing session per participant dur-ing 100 days* (standard deviation)	24.45 (2.77)
Mean number of days with no toothbrushing sessions per participant dur-ing 100 days* (standard deviation)	40.39 (10.79)

Key:
* = index regulated to 100 days for all participants.

registration site per tooth and applied to the same six index teeth as used in the plaque measurement.[15] If bleeding occurred within ten seconds after probing, bleeding was registered as value 1, and in the case of no bleeding, as value 0. A bleeding index with a value ranging between 0 to 1 was then calculated in the same manner as the plaque index.

The study period was planned to last 100 days and with a three-month follow-up after the intervention. Caregiving staff were instructed that they should perform toothbrushing twice a day for two minutes and no less than one minute once a day.

In order to avoid registration of accidental activations of the powered toothbrushes as a 'toothbrushing event', a minimum accumulated activation period of 30 seconds during a ten-minute duration was set in the CARIOT gateway. This implies that all accumulated toothbrushings below 30 seconds were recorded in the database, but that they were discarded from the email reporting and would not be counted as a 'toothbrushing event' during data analysis.

After the intervention period, the clinical registration was repeated and the telemonitoring gateways were removed. The powered toothbrushes were kept by the participants after the end of the project. Three months after the intervention period, plaque and bleeding evaluation was repeated once more for follow-up.

SPSS was used in the data analysis. Toothbrushing activity was described by means of proportions and frequencies. In case of missing data, the available data were extrapolated to 100 'toothbrushing days'. In order to compare the clinical data at baseline after intervention and at the three-month follow-up, non-parametric statistics were applied since the clinical variables could not be considered as continuous variables. Wilcoxon signed-rank test was applied in the case of single samples and Mann-Whitney U test was applied in the bivariate analyses. Correlation analyses (Kendall's tau) were performed in order to detect any correlation between bleeding and plaque in relation to the frequency and duration of the toothbrushing sessions. Although the clinical measurements cannot be considered as continuous variables, they are presented by their means for illustrative purposes.

Results

Out of 20 enrolled participants, 19 successfully completed the trial, while one participant passed away after the intervention period, but before the three-month follow-up. In Table 1, the participants are described by their demographics.

The automated data collection was overall successful. Data from 1,960 of the 2,000 possible 'toothbrushing days' (from the 20 participants during 100 days) were registered during the intervention period. Of these, 28 registrations were missing due to the gateway devices being unintentionally turned off, or the participants leaving the nursing home or otherwise disconnecting their devices, while 12 days were missing due to gateway technical communication failures. The missing data correspond to 2% of the expected events and the dataset was adjusted to reflect this. Table 2 presents the frequency and duration of the toothbrushing sessions, and Table 3 presents the total and relative number of toothbrushing events ordered into 'duration groups', of which the two in the top represent full compliance and the second row represents partial compliance, covering both morning and evening toothbrushings.

Plaque and bleeding index at baseline, after intervention and three months following the end of the intervention are described in Table 4. and illustrated in Figure 1 and Figure 2 respectively.

Furthermore, the mean changes in bleeding and plaque index from baseline, after the 100-day intervention and at the three-month follow-up are presented in Table 5. Statistically significant reductions in bleeding index ($p < 0.001$, Mann-Whitney U test) and plaque index ($p < 0.05$, Mann-Whitney U test) were observed from baseline and until immediately after the intervention. However, no such reduction could be observed when the variables were compared from baseline to three months after intervention. With respect to correlation between the clinical measurements and the variables related to toothbrushing activity, no statistically significant relations (Kendall's tau) could be observed between any of the clinical measurements and any of the different variables related to the toothbrushing activity.

Table 3 The total number of toothbrushing events registered at different toothbrushing durations during morning and evening toothbrushings

Duration	Morning toothbrushing		Evening toothbrushing		Total toothbrushings	
	N	%	N	%	N	%
≥120 seconds*	95	4.8%	91	4.6%	186	4.7%
60–119 seconds	551	28.1%	597	30.5%	1,148	29.3%
30–59 seconds	347	17.7%	322	16.4%	669	17.1%
10–29 seconds	106	5.4%	73	3.7%	179	4.6%
0–9 seconds	861	43.9%	877	44.7%	1,738	44.3%
Total brushings	1,960		1,960		3,920	

Key:
* = 120 seconds was used as the recommended brushing duration provided to participants

Table 4 Mean plaque index and bleeding index at baseline, after the intervention and at three months after the intervention at follow-up

Index	At baseline	After intervention	3 months after intervention
Plaque index	2.1	1.3*	1.9
Bleeding index	0.52	0.19**	0.50

Key:
* = $p < 0.05$.
** = $p < 0.001$ (Mann-Whitney U test).

Table 5 Changes in bleeding and plaque index from baseline, after the 100-day intervention and three months after intervention (follow-up)

Changes in bleeding and plaque index	Amount
Mean changes in bleeding index from baseline to the end of the intervention (standard deviation)	0.33 (0.40)*
Mean changes in bleeding index from baseline to the three months follow-up after the intervention (standard deviation)	0.03 (0.42)
Mean changes in plaque index from baseline to the end of the intervention (standard deviation)	0.77 (1.12)**
Mean changes in bleeding index from baseline to the three months follow-up after the intervention (standard deviation)	0.06 (1.06)

Key:
* = $p < 0.01$.
** = $p < 0.001$ (Wilcoxon signed-rank test of median = 0).

Discussion

The study investigated the practicality of using telemonitoring-enabled powered toothbrushes to determine the compliance levels of oral care tasks in the nursing home setting, as well as the resulting changes in plaque and bleeding indexes.

In order to accurately determine compliance levels and determine the relevance and practicality of our approach, reliable data collection was considered important to establish. Data collection in the intervention period was successful overall, with 98% of all participant 'toothbrushing days' being recorded. The 2% of missed days were either due to technical problems, mainly the gateway power being turned off, or due to a participant not being home for a period. Thus, the collected dataset is considered valid for further analysis, and the method of data collection seems relevant and practical to use in the nursing home setting.

In terms of toothbrushing compliance, none (0%) of the participants had their teeth brushed for all 100 days of the intervention period. During the intervention period, 75% of participants would get their teeth brushed at least once on any given day. In other words, on average, 25% of the days in the intervention period were without toothbrushing. In the days with toothbrushing sessions, 40% had one toothbrushing session and 35% had two toothbrushing sessions.

On average, participants had their teeth brushed for around one minute, which was the minimum time given in the instructions provided to the participating caregiving staff and patients (Table 2).

Less than 5% of the toothbrushings reached the recommended duration of two minutes (Table 3). However, the 'minimum toothbrushing duration' of one minute was achieved in around 30% of the toothbrushings (Table 3). Thus, full or partial compliance was achieved in around a third of all toothbrushing events (35%).

The reductions in plaque and bleeding index levels were significant from baseline to the end of the intervention period, but not from baseline and until follow-up. Thus, it seems that the initial significant gains in the oral health status (plaque and bleeding scores) of the participants were lost somewhere between the end of the intervention period and follow-up. Other studies of preventive oral health programmes in nursing homes have shown the same pattern of lack of lasting effect.[16]

The improvement with respect to bleeding and plaque is possibly the result of a Hawthorne effect, where the combination of the presence of the powered toothbrushes, the telemonitoring gateways and the added attention caused by the project information likely led to an increased focus on the toothbrushing efforts during the intervention period. This could arguably have led to the improvements in plaque and bleeding index levels. After the trial period, the telemonitoring gateways were removed, but

the powered toothbrushes were left with the participants and their caregivers. Thus, as the achieved trial improvements in plaque and bleeding indexes were lost by the time of the three-month follow-up, it seems that the availability of powered toothbrushes was unlikely to be the sole explanation for the temporary improvements in plaque and bleeding index levels achieved during the trial period. Whether it was the combination of telemonitoring gateways and powered toothbrushes which created the improvements in plaque and bleeding scores, or whether there are other explanations, remains unanswered and requires further work. Thus, whether a permanent monitoring strategy could prove more effective in retaining the improvements in plaque and bleeding index levels would be highly relevant to investigate in future studies.

The study was done in the field, which implies a range of practical challenges for the clinical registration effort. Oral examinations of this type among weaker elderly citizens have a range of ethical implications which must be respected. Thus, it was not deemed ethical to perform calibration of the clinical examination procedures, as repeated examinations would have caused unreasonable discomfort to the participants.

Another weakness of the study was the decision to classify all toothbrushings below 30 seconds as a 'missed toothbrushing'. While the recommendations provided to the staff and participants were that two minutes were optimal and one minute would be minimal, it could be argued that 10–30 seconds of toothbrushing does constitute some relevant level of oral care. In total, around 5% of all toothbrushings were between 10–30 seconds in duration.

Future studies should go beyond the 100-day intervention period in order to provide better insights into the long-term effects of introducing a toothbrushing monitoring intervention.

To the best of our knowledge, automated data capture and telemonitoring of toothbrushing sessions has not been previously performed in the nursing home setting. As such, the approach of this study constitutes a novelty in our ability to better understand oral care compliance levels in the nursing home setting, and the effect it can have on plaque and bleeding index endpoints. Other relevant endpoints could be considered; for instance, the incidence of pneumonia, hospitalisations and death, but also in terms of quality of life of the nursing home residents, as well as perceived usefulness as seen from management, staff and relatives. The necessity to improve oral care compliance and oral health status has been stressed in several studies.[1,3,17,18] Several of these studies also tried to uncover the causes of suboptimal oral care.[2,3,18] One study pointed out that a high knowledge level on the subject among the caregiving staff is an important factor in increasing compliance and oral health status.[19] Providing automated feedback to caregiving staff and management using telemonitoring equipment could arguably be used to increase the level of knowledge among both caregiving staff and management.

In a recent study on the barriers to obtaining good results with oral care programmes, the authors point out that it is mainly a matter of staff motivation and attitude that needs to be addressed, even though many of the challenges faced are due to the residents often being frail, ill or dying, and residents acting aggressively and refusing to receive assistance with oral care activities.[3] Projects aiming at increasing oral hygiene in nursing homes have previously been successfully implemented; however, a review found that once the projects end, the effect wears off fairly quickly.[16] These findings are in line with our results, where a significant positive effect was found after 100 days, but already three months after the end of the intervention, the effect had disappeared. It could be argued that maintaining permanent monitoring could lead to better oral care compliance and a lasting improvement in oral status. However, no data support such claims, implying the need for more work.

A related study on oral care compliance, with a focus on the automated data capture of frequency and duration, has been reported in a UK study by McCracken *et al.*[13] The study involved 14 participants, all of whom were patients attending a dental clinic over the span of 16 weeks. Toothbrushing frequency and duration were registered using a purposely built data logger system, which had been attached to the toothbrushes without the knowledge of the participants.[13] McCracken *et al.* found that only 34% of all recorded toothbrushing sessions succeeded in reaching the two minutes' total recommended brushing time representing 'full compliance'.[13] In comparison, our results found that less than 5% of all brushing events reached the recommended two-minute duration, while 30% would reach at least a one-minute duration. The McCracken *et al.* study reported several technical issues that should be improved before implementing a full-scale solution, including one of three main conclusions that: 'Further development of this technology will need to include date stamping of data for a true comparison to sophisticated brushing diaries'.[13] Such date and time stamping were achieved in our technical setup, including the ability to use radio-based real-time network delivery of the measurements, allowing for the permanent installation of the gateways in the home of the individual residents, without a need for manually collecting the gateways in order to get access to the data.

The data collection and monitoring technology used in our study have proven to be reliable and practical to use in the nursing home setting, and with new types of information-sharing interfaces being developed, the technology will be able to deliver real-time status information to caregiving management, staff and the residents themselves, which would allow for additional experimentation into future oral care compliance support for caregivers and residents, as well as more advanced decision support to caregivers and management.

Our study has several limitations and more work is needed. In particular, a larger study population, a longer study period, as well as a well-matched control group are relevant.

Alternative support platforms and utilities could be considered for reminding users, including smartphone apps. With an estimated 78% of adults possessing a smartphone, these could have the potential to positively impact oral health behaviours.[20] While this seems a promising approach, care should be taken to design such apps for nursing home residents and staff.

While our study results indicate that telemonitoring is relevant and practical to introduce in the nursing home setting, the study did not consider whether the resulting benefits, including the cost-saving potential of introducing the intervention, can justify the costs. This would require a well-planned health technology assessment. However, the total investment costs of acquiring 20 telemonitoring gateways and powered toothbrushes are estimated to be around €10,000 in total, not including any yearly fees for hosting, service and support, which is estimated to be around €2,000 per year.

Conclusion

It is relevant and practical to equip nursing home residents with telemonitoring-enabled powered toothbrushes. From the technical perspective, 98% of all brushings were successfully collected by the telemonitoring system, and the information was successfully shared with researchers and the nursing home management. A significant improvement was found in the plaque and bleeding indexes of the participating nursing home residents. However, the gains achieved from baseline and until the end of the study were apparently lost again at the three-month follow-up. Only a minority of brushings (5%) were in compliance with the two-minute brushing duration recommendation, while around 30% were in compliance with the 'minimum-recommendation' of a one-minute brushing duration. A large proportion of residents were either provided with only one daily brushing on average (25%) or even with no brushings (40%).

Conflict of interest

The authors declare that there are no conflicts of interest.

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