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Self-monitoring to improve home-based oral hygiene in seniors

Introduction: In order to achieve an optimal brushing result when performing self-responsible home-based oral hygiene, patients should be able to self-monitor both their brushing process and the cleaning result. This pilot study conducted in cross-over design aimed to determine if an app or an abacus can aid patients in implementing the "CIOTIPlus" tooth brushing system and technique when performing self-responsible home-based oral hygiene.

Methods: Sixteen participants (8 female, 8 male; average age: 72.6 ± 4.2 years) were included in the study. The study was divided into 3 phases. In each phase, a different tool (self-developed app or "CIOTIPlus-Abacus") was used to support self-monitor home-based oral hygiene. In the baselinel examination (t0), in addition to the general anamnesis, the DMF-T/S and PSI, QHI and mAPI were recorded. The participants recorded their home-based oral hygiene for 3 weeks by noting the cleaned tooth surfaces/areas in each phase. In phase 1 (t1), the documentation was performed solely by using the app. In phase 2 (t2), the documentation ensued through the use of the app as well, but in contrast to t1, more functions were accessible on the app. In phase 3 (t3), the daily home-based oral hygiene was recorded using an abacus ("CIOTIPlus-Abacus"). The participants were also asked to fill out a questionnaire at t0, t2 and t3.

Results: In the basic examination (t0), the participants showed an average QHI_{t0} of 2.1 ± 0.7 and an average $mAPI_{t0}$ of 3.5 ± 0.6. At t1, the subjects showed significantly lower plaque-index values (PI values) in the area of the smooth and proximal surfaces (QHI_{t1} 1.6 ± 0.6; p = 0.004; $mAPI_{t1}$ 2.9 ± 0.7; p = 0.003). At time t2, compared to t0 and t1, the average PI values were again significantly lower in the area of both the smooth (QHI_{t2} 0.8 ± 0.4; p < 0.0001) and proximal surfaces ($mAPI_{t2}$ 1.7 ± 0.5; p < 0.0001). Fourteen participants (7 female, 7 male) were included in phase 3. The PI values in the area of the smooth and proximal surfaces at time t3b were also significantly lower in comparison to both t0 and t1. At time t3b, the PI value in the area of the smooth surfaces did not differ significantly compared to t2 (QHI_{t2}–QHI_{t3b}; p = 0.147), but the PI value in the area of the proximal surfaces was significantly lower ($mAPI_{t2}$–$mAPI_{t3b}$; p = 0.024).

Conclusion: The results of this pilot study show that an app or an abacus are suitable tools for supporting patients to self-monitor their home-based oral hygiene, which could lead to significantly improved oral health.

Keywords: self-monitoring; self-responsible home-based oral hygiene; CIOTIPlus-App; CIOTIPlus-Abacus

Introduction

Caries and periodontitis are biofilm-associated diseases with multifactorial causes. In addition to regular visits to the dentist and dietary control, the efficient removal of oral biofilm plays a major role in the prevention of these diseases. The removal of biofilm is not only the responsibility of the dental professional, but primarily that of the patient who should carry out regular home-based oral hygiene [5]. Self-responsible home-based oral hygiene is thus an essential component for maintaining oral health.

The oral health awareness of the German population has increased significantly in recent years. In the Fifth German Oral Health Study (DMS V), between 70–85 % of the respondents, depending on age group, were convinced that they could contribute "very much" or "much" to maintaining or improving their oral health [17]. Patients therefore appear to be well aware that the removal of plaque/biofilm as part of self-responsible home-based oral hygiene is of great importance in the prevention of caries and periodontitis. Especially in the young senior age group (65 to 74 years), a significantly increased awareness of their own oral health was observed in DMS V [17]. However, DMS V also shows that a relatively large number of patients are still affected by caries (especially root and crown margin caries) and inflammatory periodontal diseases. Successful prevention concepts, combined with advances in the field of restorative dentistry, have made it possible to preserve natural teeth for much longer or even for the entire lifespan [19]. A clear trend towards

"tooth preservation in old age" (significant reduction in tooth loss) is evident [17]. Yet, the more teeth are preserved, the more they are exposed to the risk of disease such as periodontitis or caries. The cause of increased susceptibility to root or crown margin caries in older people is multifactorial (e.g. increased proportion of exposed root surfaces or crown margins, extensive prosthetic restorations, inadequate plaque removal, reduced salivary flow [drug-induced], previous periodontal therapy) [1, 6, 15, 20].

Regarding the prevalence of periodontitis, DMS V shows that 75.4 % of younger seniors suffer from moderately severe (every second; 50.8 %) or severe periodontitis (nearly every fourth; 24.6 %) and 80.6 % of older seniors (75- to 100-year-olds) from moderately severe (every second; 50.5 %) or severe periodontitis (nearly every third; 30.1 %) [17]. However, since the disease increases with age, the demographic trend suggests that the need for treatment is likely to increase in the future.

There is now ample evidence from epidemiological, clinical and experimental studies to suggest that periodontal infections are not only influenced by systemic factors, but that they themselves can produce systemic effects [18]. Oral health, meaning the unrestricted functionality and freedom from inflammation and discomfort, is an important component of general health and of a healthy diet and is thus closely linked to quality of life [7, 24]. One can only live up to the motto "health begins in the mouth" if a well-functioning and well-maintained masticatory system is present. The effectiveness of good home-based oral hygiene, combined with regular prophylactic dental care, for preventing caries and periodontitis has been demonstrated in studies [2, 5].

In order for patients to achieve optimal self-responsible home-based oral hygiene results, they should have the opportunity to independently assess/monitor both their cleaning process and result. Many patients seem to find it difficult to regularly implement a certain system of daily dental and oral hygiene. There are various possibilities for patients to self-monitor their cleaning process or system. In the digital age, apps offer the possibility of assisting patients in performing their daily dental and oral hygiene. However, most of the "tooth brushing apps" which are currently available on the market can only be used in combination with a corresponding electric toothbrush [16]. The number of apps which can be used together with a manual toothbrush is limited and is mainly directed towards children and adolescents [16]. In a qualitative analysis of the free apps, which are currently available on the market, and which are suited for use with manual toothbrushes, 5 "tooth brushing apps" were compared; from the 5 apps, only 2 of them were suited for adults [16]. The analysis revealed that in all apps, the implementation of a clear system of tooth brushing and reminder functions promotes regular oral hygiene [16]. The authors concluded that "tooth brushing apps" also have the potential to contribute to dental hygiene education for adults, although most apps provide insuffi-
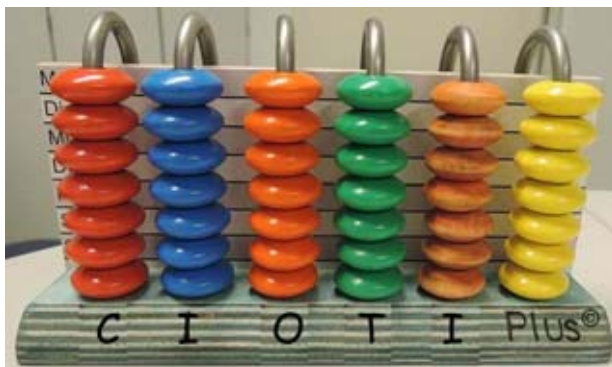

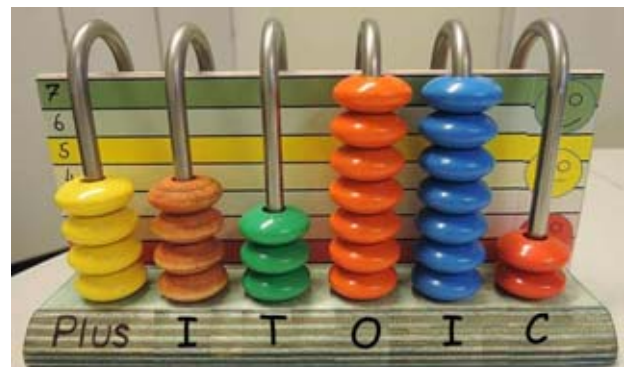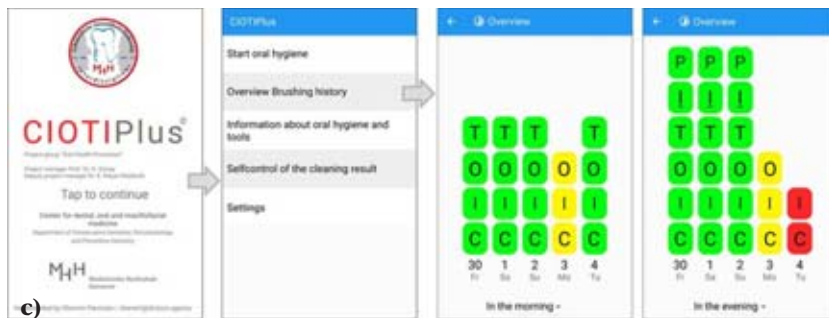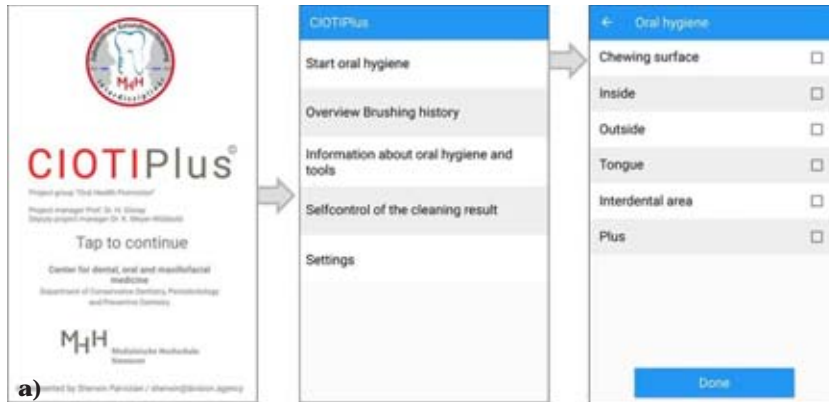**Figure 1a** Front view of the "CIOTIPlus-Abacus"

Figure 1b Back view of the "CIOTIPlus-Abacus"

Figure 2a The user can mark the individual cleaned surfaces/areas by touching the boxes in the "start oral hygiene" submenu in the CIOTIPlus-App.

Figure 2b Confirmation in the submenu "start oral hygiene" in the CIOTIPlus-App. In this submenu, a feedback is given based on whether the system has been implemented. Depending on the number of marked areas, a different smiley appears. The "red smiley" indicates an inadequate implementation of the system. The "yellow smiley" indicates a satisfactory implementation and the "green smiley" indicates a complete implementation of the system.
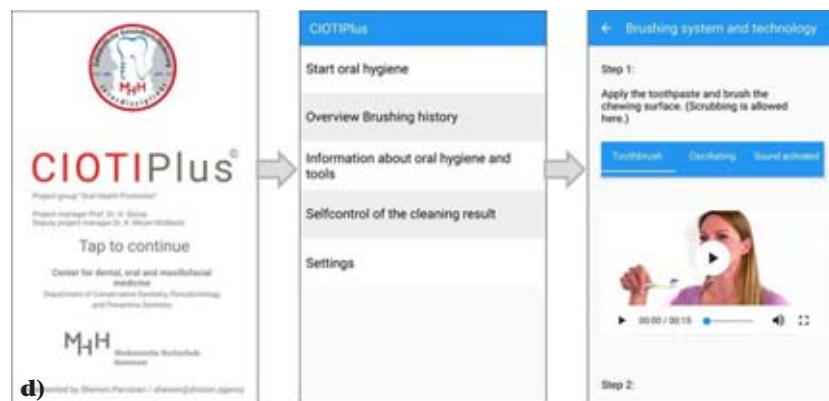
Figure 2c A graphic in the submenu "overview brushing history" in the CIOTIPlus-App illustrates the components of the "CIOTIPlus" system performed by the user per day and time of day.

Figure 2d In the submenu "information about oral hygiene and tools" in the CIOTIPlus-App, the user has access to texts and videos which explain the individual steps of the "CIOTIPlus" system.

cient instructions regarding brushing techniques and others contain too many tools which distract users from the actual purpose of dental and oral hygiene [16]. It should also be considered that apps are not suitable for everyone. Many older people, especially, use newer technical devices less than younger ones.

In order to provide these patients with the possibility to self-monitor their home-based oral hygiene, our working group "oral health care promotion interdisciplinary" initially developed an "oral hygiene protocol" in which the patients could record the system they had adopted on a daily basis. Particularly in the eve-

ning, it is recommended that patients implement the "CIOTIPlus" system. When using the "CIOTIPlus" tooth brushing system, the sequence of brushing begins on the **c**hewing surfaces, continues onto the **i**nside surfaces and finishes on the **o**utside surfaces. This is then followed by the cleaning of the **t**ongue and the **i**nterdental spaces. After this procedure, in a separate step, the patients should systematically brush the already cleaned tooth surfaces and gums with an equal pea-sized amount of toothpaste for at least one minute using small circular movements (**Plus**) [10–14]. We evaluated the use of the protocols in a study and were

able to show that such protocols work well for short periods of time when self-monitoring the brushing process and can thereby improve oral hygiene [10]. However, such simple protocols are often not very attractive for the patient in the long term. For this reason, we have additionally developed a type of abacus (Fig. 1a and b). With this tool, the patient has the chance to record the "CIOTIPlus" tooth brushing system and technique daily/weekly in an easy and entertaining manner. This in turn increases the motivation to use this tool for the purpose of documenting and self-monitoring. Unfortunately, however, no evaluation can be con-

ducted over a longer period of time which is why we have also developed an app (Fig. 2a–d).

As part of a pilot study in crossover design, it was evaluated if the app described above or the "CIOTI-Plus-Abacus" can assist patients in implementing the "CIOTIPlus" tooth brushing system and technique during self-responsible home-based oral hygiene.

Methods

The study participants were patients from the recall system (supportive periodontal therapy) belonging to the Department of Conservative Dentistry, Periodontology and Preventive Dentistry of the Hanover Medical School. The patients were between 67 and 79 years old.

An important exclusion and inclusion criterion for the selection of participants was their general state of health. The following diseases/conditions were defined as exclusion criteria:
- severe general diseases,
- mental or physical disabilities which do not permit cooperation,
- xerostomia,
- patients having exclusively implant-supported restorations,
- heavy smokers.

Furthermore, the participants had to have sufficient remaining teeth (at least 20 natural teeth). The patients were randomly included in the project if they presented interest upon being requested to participate in the project. Participation in the project was voluntary and could be discontinued at any time without giving reasons. The project received a positive vote from the ethics committee of the Hannover Medical School (vote no.: 8512_BO_K_2019).

Description of the "CIOTIPlus-App"

A self-developed app was installed on a tablet PC (Lenova Tab E7 TB-7104F 7"TN Display). The tablet was not connected to the Internet. Neither the tablet PC nor the app recorded or saved any personal or patient-related data (e.g. name, age, gender, date of birth). The app included 2 phases. In phase 1, the user only could self record which tooth surfaces/areas had

been brushed during home-based oral hygiene (chewing surfaces, inside surfaces, outside surfaces, tongue, interdental spaces, plus) (Fig. 2a). When the user started the program, the day and time were registered by the program. When the program ended, the time (tooth brushing time) was also recorded by the program. In phase 2, the user could access additional information regarding the "CIOTIPlus" tooth brushing system. The user now had the opportunity to retrieve information regarding the system at any time in image, text and video form (with sound) (Fig. 2d).

Also in this case, the user once again recorded the tooth surfaces or areas which were brushed as part of their home-based oral hygiene. The program automatically recorded the day, start time and duration (tooth brushing time) until the point when the user finished using the program. Furthermore, after the individual tooth surfaces/areas were recorded into the program, the program had the function of reminding the user whether or not particular tooth surfaces/areas were considered. The user then had the possibility to brush these missing tooth surfaces/areas and to record them as brushed (Fig. 2b).

Description of the "CIOTIPlus-Abacus"

This special abacus was made of wood and metal (robust and moisture resistant) (Fig. 1a and b). It consists of 6 metal arches. Each arch possesses 7 wooden beads which represents a component of the "CIOTIPlus" system. On the abacus' base, the abbreviations corresponding to the "CIOTIPlus" system were drawn in front of the respective metal arch. The corresponding 7 wooden beads have different colors depending on the component of the "CIOTIPlus" system. The front side of the vertical board is marked with the days of the week; the back side is marked with the numbers 1 to 7 and with colored lines. Every evening after the participant has finished their oral hygiene procedure, the wooden bead corresponding to the surface/area which the participant has brushed is moved from the front side to the back side

of the abacus. On the back side, the participant can check their daily hygiene routine. At the end of the week, the number of wooden beads on the back side presents the participant with an overview of the surfaces/areas that may have been neglected during home-based oral hygiene. This visual aid is intended to promote discipline.

Study design and recorded clinical parameters

All examinations were performed by a practitioner with the help of an assistant. For all participants, the baseline examination (t0) comprised of a general anamnesis, a detailed oral examination and the recording of the periodontal screening index (PSI). The plaque was made visible with the aid of a plaque disclosing agent (Mira-2-Ton®, Hager & Werken, D-Duisburg). Afterwards, magnifying glasses (2.5x, Orascoptic, Fa. Sigma Dental) were used to determine the modified Quigley-Hein Plaque Index (QHI) according to Turesky [23] as well as a modified plaque index based on the Quigley-Hein Plaque Index (modified Proximal Plaque Index – mAPI) for the purpose of assessing the extent of plaque in the proximal areas [11]. Before the initial examination, patients were asked to fill out a questionnaire. The questions were mainly multiple-choice and included topics such as "oral hygiene" and "evaluation and assessment". After completing the questionnaire, the patients were shown the stained plaque on their teeth surfaces using a magnifying mirror and a mouth mirror. They were again asked to appraise their oral hygiene using a questionnaire. In order to create uniform starting conditions, the test persons received a professional tooth cleaning, which included cleaning and polishing of both the smooth and proximal surfaces. The "CIOTIPlus" brushing system was explained, demonstrated and practiced. In addition, all participants received an information leaflet which explained the system once again in image and text. The participants were instructed that they should practice implementing the system at least once daily during oral hygiene, es-

pecially in the evening. All patients received a tablet PC (Lenova Tab E7 TB-7104F 7"TN Display) on which the self-developed app described above was installed. With the help of the app, the patients were expected to record the systematic procedure as part of their daily home-based oral hygiene. The patients were instructed in how to use the tablet PC and the program. At this point, the user only had access to "phase 1" of the program. The participant was asked to record their daily home-based oral hygiene (noting the cleaned tooth surfaces/areas) using the app for 3 weeks.

After 3 weeks, re-examination (t1) was performed. The plaque indices (QHI and mAPI) were recorded after the plaque was made visible by staining and then the teeth (have been) cleaned. Afterwards, "phase 2" was activated on the tablet PC. The participants were asked to record their daily practice of home-based oral hygiene (noting the cleaned tooth surfaces/ areas) for 3 weeks using the "CIOTI-Plus-App".

After 3 weeks, a re-examination (t2) was performed. The plaque indices (QHI and mAPI) were determined after the plaque was made visible by staining and then the teeth were cleaned. Before the examination, the patients were asked to fill out a questionnaire which consisted of multiple-choice questions regarding the tooth brushing system and the "CIOTIPlus-App".

After t2, a 6-month break in the form of a "washout phase" ensued in order to avoid a possible "Hawthorne effect" in phase 3 (t3). At time t3a, a re-examination (QHI/mAPI), professional tooth cleaning and fluoridation were performed. The "CIOTI-Plus" tooth brushing system (+ leaflet) and the use of the "CIOTIPlus-Abacus" (phase 3) were explained to the participants. The participants were asked to record the total number of beads per component of the "CIOTIPlus" system at the end of each week in a documentation sheet (Fig. 3). The participants were once again requested to record their home-based oral hygiene in the evening using the "CIOTI Plus-Abacus" for 3 weeks.

Figure 3 Documentation sheet for phase 3

After these 3 weeks, the last examination (t3b) was performed. Analogous to t1 and t2, the plaque indices (QHI and mAPI) were recorded after plaque staining. Then, the teeth were cleaned and fluoride was applied.

Figure 4 summarizes the project's timeline (flowchart of the project).

Data protection and statistical analysis

The evaluation performed in this project was anonymous. The participants were informed that their personal data would be kept anonymous and that it would be exclusively used for the purpose of data collection. The tablet was not connected to the Internet at any time. Neither the tablet PC nor the "CIOTIPlus-App" recorded or stored any patient-related data (e.g. name, age, gender, date of birth). A consent form was signed by each participant.

Data analysis was performed with the statistical analysis program SPSS/ PC Version 25.0® for Windows (SPSS Inc., Chicago, IL, USA). All collected data was analyzed through pseudonymization. First, mean values, standard deviations and frequencies were calculated for the descriptive statistics. The collected values arising from repeated measurements within a group were analyzed for variance using the paired T-test. The statistical significance level was set at $p < 0.05$.
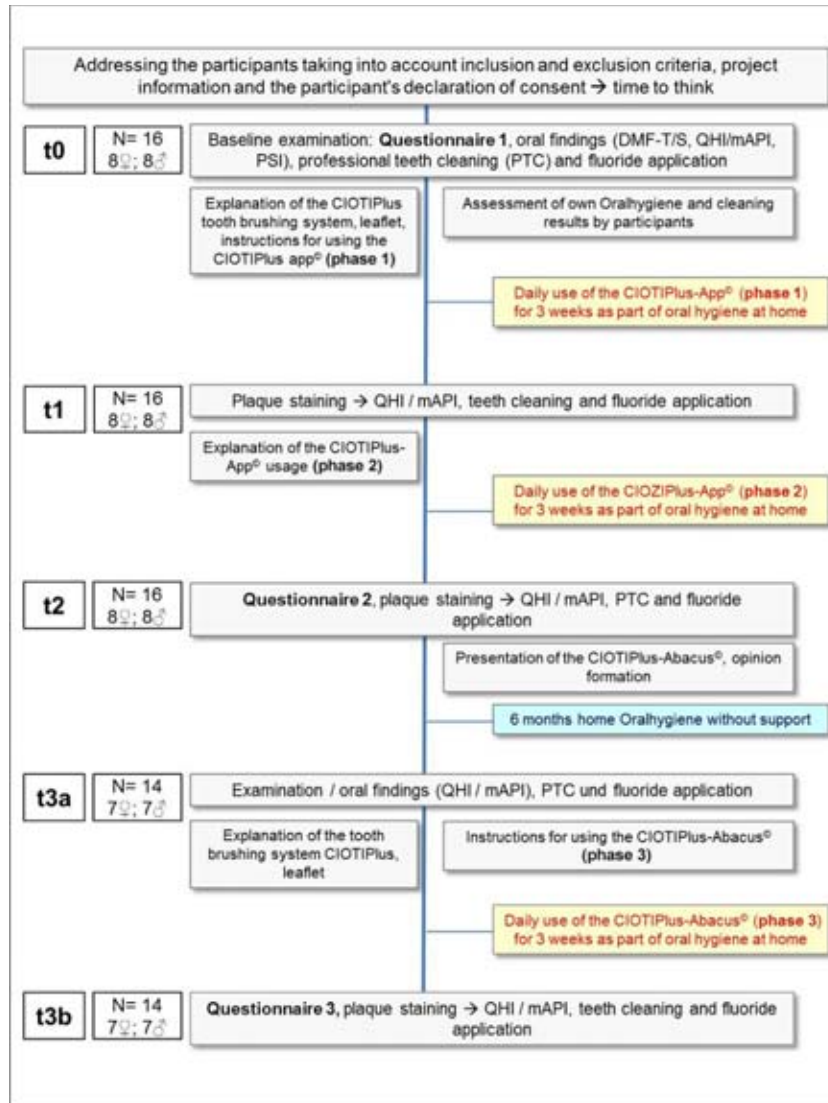
Figure 4 Flowchart of the project

Results

Clinical parameters

The study included 16 participants (8 female, 8 male) with an average age of 72.6 ± 4.2 years. In the basic examination (t0), the subjects showed an average QHI_{t0} of 2.1 ± 0.7 and an average $mAPI_{t0}$ of 3.5 ± 0.6. In the second examination (t1), the participants showed significantly lower average plaque index values in the area of the smooth (QHI_{t1} 1.6 ± 0.6; $p = 0.004$) and proximal surfaces ($mAPI_{t1}$ 2.9 ± 0.7; $p = 0.003$) when compared to t0. In the third examination, compared to t0, significantly lower average plaque index values were once again detected on both the smooth (QHI_{t2} 0.8 ± 0.4; $p < 0.0001$)

and proximal surfaces ($mAPI_{t2}$ 1.7 ± 0.5; $p < 0.0001$). The plaque index values for the smooth and proximal surfaces at time t2 were also significantly lower compared to time t1 (QHI_{t1}–QHI_{t2}; $p < 0.001$; $mAPI_{t1}$–$mAPI_{t2}$; $p = 0.033$) (Fig. 5).

In phase 3, 14 participants (7 female, 7 male) remained to be included. At time t3a, the participants showed an average QHI_{t3a} of 1.9 ± 0.5 and an average $mAPI_{t3a}$ of 2.9 ± 0.7, while at time t3b, they had an average QHI_{t3b} of 0.7 ± 0.4 and an average $mAPI_{t3b}$ of 1.4 ± 0.6. The plaque index values on the smooth and proximal surfaces at time t3b were also significantly lower than at times t0 (QHI_{t0}–QHI_{t3b}; $p < 0.001$; $mAPI_{t0}$–$mAPI_{t3b}$; $p < 0.001$) and t1

(QHI_{t1}–QHI_{t3b}; $p < 0.001$; $mAPI_{t1}$–$mAPI_{t3b}$; $p < 0.001$). At time t3b the plaque index value in the area of the smooth surfaces did not differ significantly compared to time t2 (QHI_{t2}–QHI_{t3b}; $p = 0.147$), but the plaque index value in the area of the proximal surfaces was significantly lower $mAPI_{t2}$–$mAPI_{t3b}$; $p = 0.024$) (Fig. 5).

Use of the "CIOTIPlus-App" and documentation of the CIOTIPlus-System

The patients were instructed at the beginning of phase 1 to use the "CIOTIPlus" tooth brushing system at least once daily when performing oral hygiene, especially in the evening. For this reason, only the use of the app/documentation of the system in the evening was considered in the following section when analyzing the results.

On average, the "CIOTIPlus-App" was used by the participants in the evening on 24.9 ± 3.3 days in phase 1 and on 18.3 ± 2.5 days in phase 2.

Using the app, the participants recorded which part of the system (chewing surface, inside surface, outside surface, tongue, interdental spaces and plus) was performed in which order. A percentage evaluation was conducted based on app's usage. The frequency of the parts of the system documented by the participant was evaluated. Also, how often the recommended system was completely implemented and if it was performed in the correct sequence was recorded. It was determined that in phase 2, compared to phase 1, the participants documented the proportions of the system "tongue" ($p = 0.037$) and "plus" ($p = 0.016$) significantly more often. In phase 2, according to the documentation provided by the participants, all parts of the system ($p = 0.003$) were implemented in the specified order ($p = 0.016$) significantly more frequently than in phase 1.

Use of the "CIOTIPlus-Abacus" and documentation of the CIOTIPlus-System

At the beginning of phase 3, the patients were instructed to apply the "CIOTIPlus" tooth brushing system at least once daily during oral hygiene,

especially in the evening. At the end of a week, the participants were instructed to read the number of beads per component of the system from the "CIOTIPlus-Abacus" and record it in a documentation sheet (Fig. 3). The documentation sheets were completely filled out by all of the participants in phase 3, thus suggesting that the "CIOTIPlus-Abacus" was indeed used by all of the participants during the entire 3 weeks.

Based on the documentation sheets, the frequency as a percentage was calculated for each of the components of the system which was implemented by the participants. When comparing phase 3 to phase 1, all of the components of the system were implemented more frequently by the participants, although this was not statistically significant. Similarly, all components of the system except for the "tongue" were recorded more frequently in phase 3 than in phase 2. This was, however, again not statistically significant.

Analysis of the questionnaires

All participants (100 %) stated that they had already performed their daily home-based oral hygiene according to a certain system before the project. All of them (100 %) would also like to continue to use the "CIOTIPlus" system in the future. The greater majority of those surveyed consider this system to be suitable for everyday use (93.8 %) and perceive to have a "better mouth feeling" (87.5 %) after brushing according to this system. All participants (100 %) think that a control mechanism for the systematic procedure is better for the brushing result.

About two thirds of the respondents (68.8 %) stated that the "CIOTIPlus-App" was helpful for assisting them in checking their dental and oral hygiene on their own. The majority of participants would continue to use the "CIOTIPlus-App" in the future (87.6 %) and all of them would recommend the app either generally (81.3 %) or for specific groups of people/special cases (18.8 %).

With respect to the "CIOTIPlus-Abacus", all participants (100 %) stated that it helped them to check their dental and oral hygiene on their own. More than half of the participants (57.1 %) would continue to use the "CIOTIPlus-Abacus" to assist them in their daily oral hygiene. A large proportion of the respondents (85.7 %) would recommend the abacus for self-responsible home-based oral hygiene.

The majority of the respondents (78.6 %) stated that the "CIOTIPlus-Abacus" was easier to use than the "CIOTIPlus-App" as a tool for checking home-based oral hygiene. Additionally, 64.3 % would also recommend the abacus than the app.

Self-control of the cleaning result

In the basic examination (t0), it was found that patients who without visualization their plaque tended to assess their oral hygiene as being considerably much better than after visualizing it. Before the plaque was stained, 6.3 % of patients rated their oral hygiene as being "good" and 93.8 % "very good". After the stained plaque and demonstration was revealed to them, the patients were very surprised and revised their assessment; 56.3 % of them rated their oral hygiene as "good", 25 % as "moderate" and 18.8 % as "poor". The differences between the assessments before and after the demonstration of stained plaque-affected areas were statistically significant (p = 0.007). The patients' ability to self-assessment plaque after the demonstration reflects well the objective findings of the plaque indices.

Discussion

In the digital age, apps for the self-management and self-monitoring of chronic diseases (e.g. diabetes mellitus) have been successfully used for several years [8]. Similar to other areas of general medicine, dental prevention concepts can only be successful if compliance, self-responsibility and self-monitoring on the patient's behalf are ensured.

All participants claimed that the abacus helped them to self-monitor their home-based dental and oral hygiene. Only about two thirds of the respondents stated that the "CIOTIPlus-App" had supported them to self-monitor their dental and oral hygiene at home. When interpreting these results, it should be taken into account that apps are not suitable for everyone. Many older people use new technical devices less than younger ones. The reasons for this are manifold. Firstly, many older people have less contact with new technologies because they did not grow up with them and often lack an understanding of how modern technology works [22]. On the other hand, physical challenges that occur with old age, such as visual or hearing impairments, limitations in fine motor skills and cognitive limitations can also represent an obstacle [22]. In a survey, 41 % of over 1000 people over the age of 65 stated that they had difficulty operating modern technical equipment [21]. Also, in the present study, more than two thirds of those questioned stated that they found it easier to use an abacus than an app. An abacus appears to be a suitable tool for getting used to a tooth brushing system. The abacus is permanently present and it motivates or reminds, the patient to implement the system in daily dental and oral hygiene. This approach follows the "KISS principle", which stands for "keep it simple and stupid". This means that the easier something is to understand and use, the more likely it is that the user or patient will actually use it. The results of the present study support this assumption. The documentation forms for the "CIOTIPlus-Abacus" were completed filled out by all participants. Therefore, it is reasonable to conclude that the abacus was also used by all participants during the entire period of investigation. In contrast, the evaluation of the app showed that it was not used on a daily basis by the participants.

At time t1, the participants used a technical device and they recorded the performed components of the system using the "CIOTIPlus-App". However, this was only a pure documentation procedure which can be compared to oral hygiene protocols. This documentation alone already led to improved home-based dental and oral hygiene, which was reflected in the significantly lower
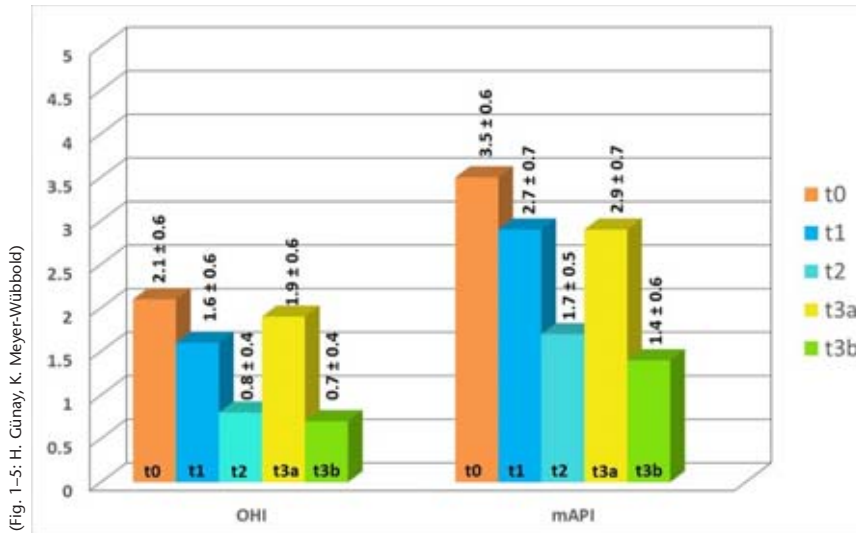
(Fig. 1–5: H. Günay, K. Meyer-Wübbold)

Figure 5 QHI and mAPI of the participants at times t0, t1, t2, t3a and t3b

plaque index values in the area of the smooth and proximal surfaces at time t1 compared to t0. At time t2, the participants not only recorded the components of the system using the app, but they also had the opportunity to access information regarding the "CIOTIPlus" tooth brushing system and technique in image, text and video form (with sound) at any time via the app. Besides this, the user received feedback after performing oral hygiene regarding whether tooth surfaces or areas had not been taken into account. The participants then had the opportunity to clean these missing tooth surfaces or areas and record this afterwards. The significantly lower plaque index values in the area of the smooth and proximal surfaces at time t2 compared to t0 and t1 suggests that this additional information is helpful for patients to self-monitor and pursue an adequate home-based dental and oral hygiene.

Between phases 2 and 3, a longer period (6 months) without further intervention was deliberately chosen in order to avoid a possible "Hawthorne effect" in phase 3. Due to phases 1 and 2, the participants could have already been experienced in implementing the system, which in turn could have distorted the results in phase 3. In order to rule out a "Hawthorne effect", the plaque index values in the area of the

smooth and proximal surfaces were again recorded at the beginning of phase 3 (t3a) and before using the "CIOTIPlus-Abacus". The values determined at time t3a clearly show that no "Hawthorne effect" occurred because the values did not differ significantly from those determined at time t0.

At time t3, the participants used a special abacus. The "CIOTIPlus-Abacus", unlike an app, is present at all times at the place for oral hygiene and should serve as a simple visual reminder and monitoring mechanism. Like at time t1, there was only a recording of the implemented components of the system using the "CIOTIPlus-Abacus". However, the significantly lower plaque index values in the area of the smooth and proximal surfaces at time t3b compared to t1 concludes that, with regard to the implementation of an adequate home-based dental and oral hygiene, the recording using an abacus appears to be more helpful than just the documentation alone using an app, which is simply based on following oral hygiene protocols. The documentation occurs in a playful way when using an abacus, while also simultaneously stimulating the motor and sensor systems. This seems to motivate and also discipline the participants more than the mere documentation via the app or oral hygiene protocols.

For the documentation using an app, the participants had to use a technical device which can only be used everywhere to a limited extent. Such technical devices are sensitive to moisture and are exposed to the risk of unintentional destruction, especially in damp rooms such as bathrooms, where daily dental and oral hygiene is usually performed. This danger does not exist with an abacus. Moreover, the documentation using an app is somewhat more demanding and takes more time than the documentation using an abacus. The technical device had to be started beforehand and also loaded in the meantime. The user was supposed to enter the individual components of the system manually in the sequence performed and could also access information or continue dental and oral hygiene after eventually receiving instructions. However, the app gave the user the opportunity to precisely view the system they had applied on a daily basis; this was possible retrospectively over a longer time consider as well. The "CIOTI-Plus-App" thus provided precise information about which components of the system were implemented in which order and when. This control mechanism does not exist when using an abacus. However, these advantages are unlikely to have played a major role for the participants in the present study, at least not for the short 3-week interval of use of the two self-monitoring tools. This is reflected both in the clinically collected plaque index values and in the results of the questionnaire.

In the basic examination, it was found that many patients find it difficult to objectively assess their own cleaning results. A pure visual check, even with magnifying aids and optimal lighting conditions, or a "tongue-feel test" to identify any plaque that may still be present, is not sufficient and cannot reveal hidden "problem" or "weak points" (e.g. interdental spaces, the inner surfaces of the teeth and the areas around the gum line). We therefore recommend that patients use plaque staining agents (e.g. staining [chewing] tablets, rinsing solutions which stain plaque) to visualize plaque at

least once a week during their home-based dental and oral hygiene. Plaque staining agents, which can make a distinction between "new" and "old" plaque are also useful. Patients should visualize the plaque both before starting and after finishing home-based oral hygiene. The first staining serves as a guide for performing oral hygiene by allowing patients to concentrate directly on the "problem" or "weak points". The second staining is then used to check the brushing result. A second staining after tooth brushing is highly recommended; studies have shown that the plaque staining agent, through the brushing process and the ingredients in the toothpaste (e.g. surfactants), is partially washed out or fades, thus making the remaining plaque no longer visible to the patient [10]. A visualization of plaque helps patients to assess their own oral hygiene. In this study, it was found that patients without visualize plaque assessed their own oral hygiene as being much better than those after visualizing it. Before demonstration of the stained plaque, 6.3 % of patients rated their oral hygiene as "very good" and 93.8 % as "good". After the demonstration of the stained plaque, patients were very surprised and reconsidered their assessment. Thereafter, 56.3 % of those surveyed rated their oral hygiene as "good", 25 % as "moderate" and 18.8 % as "poor". The differences between the Assessments before and after revealing the stained plaque-affected areas were statistically significant (p = 0.007) [12]. The patients' self-assessment after having been shown the plaque is in accordance with the objective findings of the plaque indices. However, before recommending the self-monitoring of the cleaning result, it is necessary to provide the patient with demonstrations and explanations on how the "staining agents" are used and which spatial requirements or auxiliary tools (e.g. mouth mirror, magnifying mirror or telescopic mirror with light source) are necessary for this purpose. When patients visualize plaque as part of the self-monitoring of the brushing results, they have the opportunity to recognize their own

problems and weaknesses and thus to continuously improve their brushing system and technique!

Without further intervention, the success in terms of patient compliance is likely to be short-term [3, 4]. The results of the present study support this assumption. The plaque index values collected from the participants at time t3a differed only marginally from those at time t0. Based on the previous interventions, it would have been expected that the participants at time t3a were already appropriately sensitized, which should have led to an improvement/optimization of the home-based dental and oral hygiene, and thus, to significantly lower plaque index values at time t3a compared to t0. However, between phase 2 (t2) and phase 3 (t3a), there was a 6-month period with no further intervention. In the context of self-responsible home-based oral hygiene, a permanent visual reminder with respect to the hygiene measures and system to be implemented can potentially motivate patients; for example, the continuous presence of the "CIOTIPlus-Abacus" or a small poster in the bathroom/oral hygiene area can serve this purpose. Future long-term studies should show whether there may be a need for apps for the self-monitoring of home-based dental and oral hygiene which have more functions (e.g. "live transmission" of the cleaned surfaces from the toothbrush via Bluetooth to the mobile device) in order to increase the number of long-term users. In this manner, this may improve the self-management of dental and oral health.

Conclusions

When interpreting the results, it should be taken into account that the present study is a pilot study which provides pioneering insights and considerations regarding the self-management of home-based dental and oral hygiene. Overall, it can be concluded that an app or abacus are suitable tools for assisting patients to self-monitor their home-based oral hygiene, which can significantly improve oral hygiene. However, due to the fact that an app is not suitable for every elderly patient, it is advisable that an individualized decision is

made together with the patient as to which self-monitoring option (app, protocols, abacus) is appropriate for them and to what extent it is desired. With an app, it is possible to assess the results daily, weekly or monthly, and even retrospectively, over much longer timespans. Moreover, the protocols can also be evaluated retrospectively over time. With the abacus, there is only the possibility of a daily or weekly assessment of the results. The present study could show that the integration of a self-monitoring system (e.g. an app or an abacus) into an oral prevention concept is promising. In all oral prevention concepts, self-responsibility for oral health plays a central role for a sustainable/lasting (behavioral) change.

Conflicts of Interest

The authors declare that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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