Remote Oral Hygiene Management for People with Intellectual/Developmental Disabilities Using a Smart Toothbrush

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Remote Oral Hygiene Management for People with Intellectual/Developmental Disabilities Using a Smart Toothbrush

Directed by Professor Wonse Park

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This certifies that the Master's thesis of

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ABSTRACT

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(Directed by Professor Wonse Park, D.D.S., M.S.D., Ph.D.)

Purpose

Individuals with intellectual and developmental disabilities have greater difficulty than other individuals maintaining routine oral hygiene. Advances in mobile technology are helping with health management practices, and smart toothbrushes provide proper dental care by collecting and analyzing users' toothbrushing data.

The smart toothbrush detects the user's movements and provides appropriate feedback to each individual to encourage habit correction. The purpose of this study is to analyze how the smart toothbrush affects the overall oral hygiene management of

individuals with intellectual or developmental disabilities. The purpose is to evaluate the impact on oral hygiene management and whether it is helpful in oral health management.

Materials and Methods

The number of participants was 13 in each group, a total of 26. Ultimately, of the 26 participants, two withdrew consent and two were lost to follow-up, resulting in a total of 22 participants completing the study. In the study, participants were divided into a group that first used Mombrush (MB) and then a manual toothbrush (MTB) (MB-MTB group) and a group that used a MTB and then MB (MTB-MB group), with a one-month rest period. The timeline of the study was as follows: the visit times were baseline, 1-month post-examination, 3-months post-examination, 1-month rest period, 4-month post-baseline examination, 5-month post-examination, and 7-month post-examination. At each visit, simple hygiene score (SHS) and Quigley-Hein Plaque Index (QHI) tests were performed, halitosis was measured, and microorganisms were collected.

Results

The SHS score was 3.00 ± 2.45 points at baseline in the MTB-MB group, and the score at the end of the study decreased to 1.20 ± 2.16 points. In the MB-MTB group, the score decreased from 3.6 ± 1.57 points to 3.00 ± 2.00 points at baseline, but the change was not significant. The QHI index decreased from 1.94 ± 1.03 points at

baseline in the MB-MTB group to 1.29 ± 0.76 points at the end of the study. In the MTB-MB group, it decreased from 1.75 ± 1.37 points at baseline to 1.06 ± 0.74 points at the end of the study. There was a significant difference between the two groups before replacing the toothbrush.

The baseline H_2S level in the MB-MTB group was 0.46 ± 1.36, decreasing to 0.02 ± 0.03 at the end of the study. In the MTB-MB group, the baseline level was 0.30 ± 0.74, increasing to 0.31 ± 0.69 at the end of the study. CH_3SH levels in the MB-MTB group ranged from 0.07 ± 0.21 at baseline to 0.10 ± 0.15 at the end of the study. n the MTB-MB group, they ranged from 0.87 ± 0.16 at baseline to 0.10 ± 0.13 at the end of the study. Both H_2S and CH_3SH levels showed significant differences over time in both groups, with no significant difference according to flow.

Conclusions

This study was conducted as a cross-sectional study, with participants engaging in both the control and experimental groups. In the comparison between the two groups before the rest period, using Mombrush was found to be beneficial for oral hygiene management. After the resting period, both groups showed a decrease. However, the MTB-MB group showed a slightly greater decrease, but the group using a manual toothbrush also showed an effect on the oral hygiene index. This is believed to be helpful for oral hygiene management in the MB-MTB group, as they retained memories from the time before toothbrush replacement. The results of this study demonstrated that smart toothbrushes have a positive impact on the oral hygiene of individuals with

intellectual or developmental disabilities.

However, to maintain these positive outcomes, there is a need to encourage sustained interest in oral care among individuals with intellectual or developmental disabilities.

Key Words : Intellectual disability, Developmental disability, Smart Toothbrush, Remote Oral Hygiene Management

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I. INTRODUCTION

Individuals with intellectual or developmental disabilities often encounter difficulties in brushing their teeth (Jeon et al., 2021), leading to a higher prevalence of dental caries and periodontal diseases compared to the general population without disabilities. The oral care of individuals with intellectual or developmental disabilities is typically overseen by their guardians or caregivers. (Waldron et al., 2019) The oral health of these individuals is frequently

determined by the knowledge, behavior, and attitude of their guardians and caregivers. (Cumella et al., 2000; Waldron et al., 2019; Zolfaghari et al., 2021)

For these individuals, daily toothbrushing performed in the correct manner can be the most significant means of preventing dental caries and periodontal diseases. (Chen et al., 2021) Intellectual disability refers to a condition where intellectual development is delayed or halted, resulting in a lack of behavioral ability, below-average cognitive ability, and poor learning and social adaptation abilities. It is categorized into three levels: (1) Level 1: IQ is less than 35, (2) Level 2: IQ is between 35 and less than 50, (3) Level 3: IQ is between 50 and 70.

Developmental disability involves functional and ability disorders that limit an individual's capacity to carry out daily or social activities, necessitating assistance. This may manifest as a lack of social skills, absence of interpersonal relationships, abnormal language skills, repetitive abnormal behavior, and mental retardation. Among these conditions, autism spectrum disorder is a type of developmental disorder characterized by repetitive and stereotypical patterns of behavior, interests, or activities, as well as a general social interaction impairment, lack of interpersonal relationships, and communication impairment. (Du et al. 2019)

Individuals with intellectual and developmental disabilities often face greater challenges in their daily oral hygiene management compared to others (Anders

and Davis, 2010). These difficulties primarily result in the neglect of care, leading to dental issues such as periodontal diseases and tooth decay. Despite the crucial importance of oral hygiene for these individuals, brushing their teeth can be a challenging skill (Silva et al., 2020).

Moreover, the likelihood of needing dental treatment is high due to factors such as the use of sugar-containing medications, difficulty in removing residual food particles from the oral cavity, salivary dysfunction, and excessive carbohydrate intake (Lee and Chang, 2021). Therefore, maintaining attention and participation in oral hygiene management is essential.

The recent advancement in mobile technology has provided significant assistance in healthcare. Aligned with these technological developments, a new approach to toothbrushing education using mobile devices and tablets has been introduced. Smart toothbrushes represent an example of this technological innovation. Unlike traditional manual toothbrushes, smart toothbrushes connect to smartphones via Bluetooth technology. They collect and analyze users' toothbrushing data, supporting proper brushing habits and correction through apps and services integrated into a health management platform. Smart toothbrushes detect users' toothbrushing actions in real-time, guide individuals in personalized brushing techniques, and provide feedback to induce habit correction.

However, there is limited research on the efficacy of smart toothbrushes for individuals with intellectual and developmental disabilities. With a lack of studies comparing smart and manual toothbrushes, further research is warranted to investigate the impact of smart toothbrushes on oral health.

Therefore, the objective of this study was to assess the influence of using a smart toothbrush on overall oral hygiene management, specifically in addressing plaque, bad breath, dental caries, and periodontal microbiota.

This study aimed to examine whether the use of an interactive smart toothbrush, in comparison to a regular toothbrush, had a significant impact and contributed to improved oral health management among participants with intellectual or developmental disabilities.

II. MATERIALS and METHODS

2.1. Study design

This research was carried out with approval from the Research Review Committee of Yonsei University Dental Hospital (IRB No. 2-2021-0066) and was conducted at the Department of Advanced General Dentistry and Department of Pediatric Dentistry, at Yonsei University Dental Hospital from November 2021 to November 2023.

Written consent was obtained from the legal guardians of all participants, and comprehensive information about the study was provided before their participation. To safeguard participant confidentiality, all collected data were anonymized.

The study employed a randomized, crossover clinical trial design to assess plaque removal, reduction in bad breath, and alterations in oral microorganisms. The investigation focused on the impact of using a smart toothbrush in comparison to a regular toothbrush on these oral health parameters.

2.2. Participants

The participant selection criteria were as follows; (1) individuals diagnosed with intellectual or developmental disabilities, (2) those whose guardians could either brush their teeth or assist in the brushing process, (3) individuals with 16 or more teeth, including implants or bridges, and (4) participants whose guardians could use an Android-based smartphone.

Exclusion criteria included; (1) individuals with only primary teeth, (2) those with orthodontic appliances in the oral cavity, (3) patients undergoing head and neck radiation therapy, (4) pregnant or lactating women, (5) participants who withdrew their consent, and (6) any other individuals deemed inappropriate by the researcher.

The study divided participants into two groups: one using Mombrush (MB) first followed by a manual toothbrush (MTB) (MB-MTB group) and the other using MTB first followed by MB (MTB-MB group). The sample size was calculated using the R package 'TrialSize,' with significance set at 0.05, power at 90%, standard deviation at 0.2, non-inferiority margin at 0.25, and mean difference at -0.1. This calculation resulted in 10 participants per group, with a dropout rate of 20%. Considering this, the final number of participants was determined to be 26, with 13 individuals in each group.

Participants were randomly assigned to the MB-MTB and MTB-MB groups by an independent researcher using a computerized randomization tool before

the study's commencement. Of the initially recruited 26 participants, 2 withdrew consent, and 2 were lost to follow-up, resulting in a total of 22 participants completing the study (Figure 1).

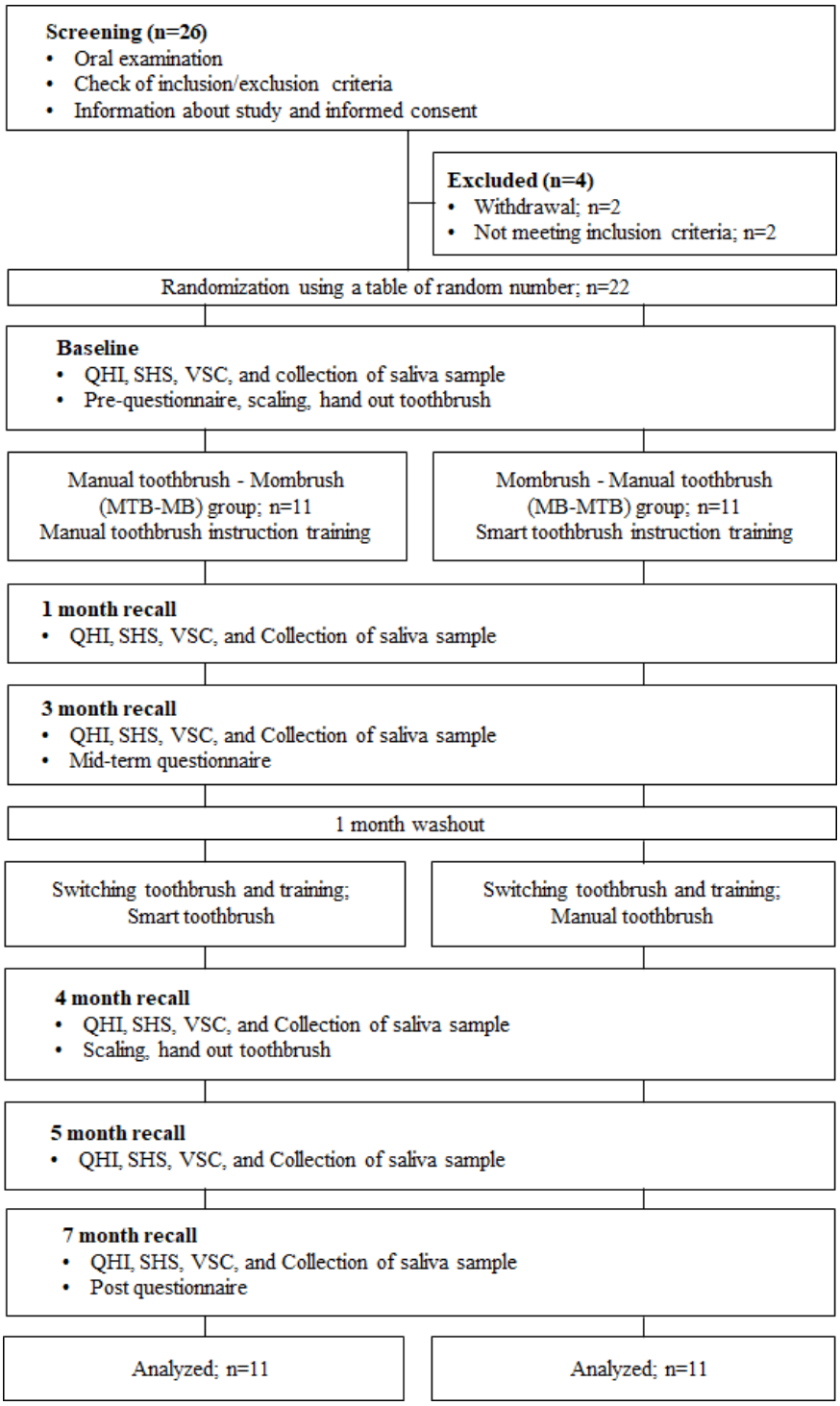


Figure 1. Study flowchart

2.3 Methods

Procedures and study test products

The toothbrushes utilized in this investigation were the American Dental Association (ADA) reference standard manual toothbrush (PRO-SYS® Sensitive Toothbrush; Benco Dental, Pennsylvania, U.S.A) and the smart toothbrush Mombrush (XiuSolution, Gyeonggi, Republic of Korea) (Figure 2).

The standard manual toothbrush solely provided training to participants and their guardians on the rotational brushing method. Mombrush distributed a Mombrush product capable of recognizing the position and angle of toothbrushing along with a standard manual toothbrush that could be connected to the product. Upon installing the Mombrush ProCare application on the guardian's smartphone, participants were instructed to brush their teeth while viewing a rotation guide video within the application.

Throughout the study period, all participants were required to brush their teeth with the provided toothbrush at least twice a day. They were explicitly instructed not to use other oral hygiene aids such as dental floss, interdental brushes, or mouthwash. Furthermore, all groups were supplied with standard fluoride toothpaste (1450 ppm NaF, Colgate® Anticavity Toothpaste Maximum Cavity Protection; Colgate-Palmolive, New York, U.S.A.) (Figure 2).

Figure 2. Tools used in the study (A) toothpaste, (B) smart toothbrush, (C) manual toothbrush

Turesky Modified Quigley-Hein Plaque Index (QHI)

Using a disclosing solution (1% neutral red) (YOUNG Dental, Missouri, U.S.A.), the maxillary right first molar (#16), maxillary left central incisor (#21), maxillary left first premolar (#24), and mandibular left first molar were identified. After staining the crown and cervical surfaces of the mandibular left first molar (#36), mandibular right central incisor (#41), and mandibular right first premolar (#44), plaque was assessed on the buccal and lingual surfaces of each tooth. A score ranging from 0 to 5 was assigned to each part (Table 1).

Table 1. Turesky Modified Quigley-Hein Plaque Index (QHI)

Score	Description
0	No plaque
1	Slight staining at the cervical margin
2	Plaque band up to 1 mm at the cervical margin
3	Plaque band wider than 1 mm but covering less than one-third of the crown of the tooth
4	Band covering at least one-third but less than two-thirds of the crown of the tooth
5	Band covering more than two-thirds of the crown plaque

Simple Hygiene Score (SHS)

For the quantitative and qualitative evaluation of plaque, frontal photographs were captured utilizing the QLF system (Qraycam®, AIOBIO, Seoul, Republic of Korea).

Employing the QA2v1.38 System (Qraycam®, AIOBIO, Seoul, Republic of Korea), a QLF system analysis program, an SHS (Plaque Surface Area Index) ranging from 0 to 5 points was assigned based on the extent of plaque adhesion. The score increased with a larger area of plaque adhesion and the scores were subsequently analyzed (Figure 3).

Volatile Sulfur Compounds (VSC)

Halitosis was assessed using Twin Breasor II (iSenLabInc., Seoul, Republic of Korea) to quantify hydrogen sulfide (H_2S) and methyl mercaptan (CH_3SH). Participants held a dedicated straw in their mouths and breathed nasally for 50 seconds, followed by 10 seconds. The analysis was performed over 150 seconds (Figure 4).

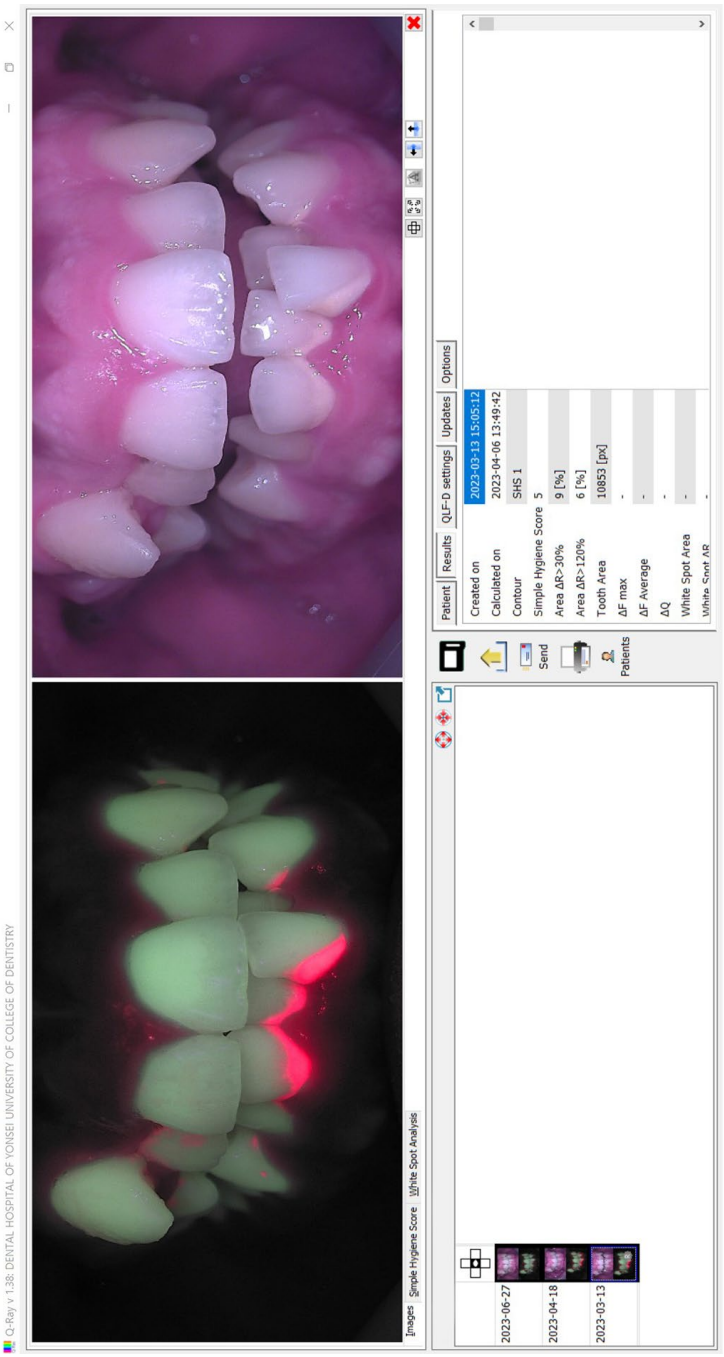


Figure 3. QLF system

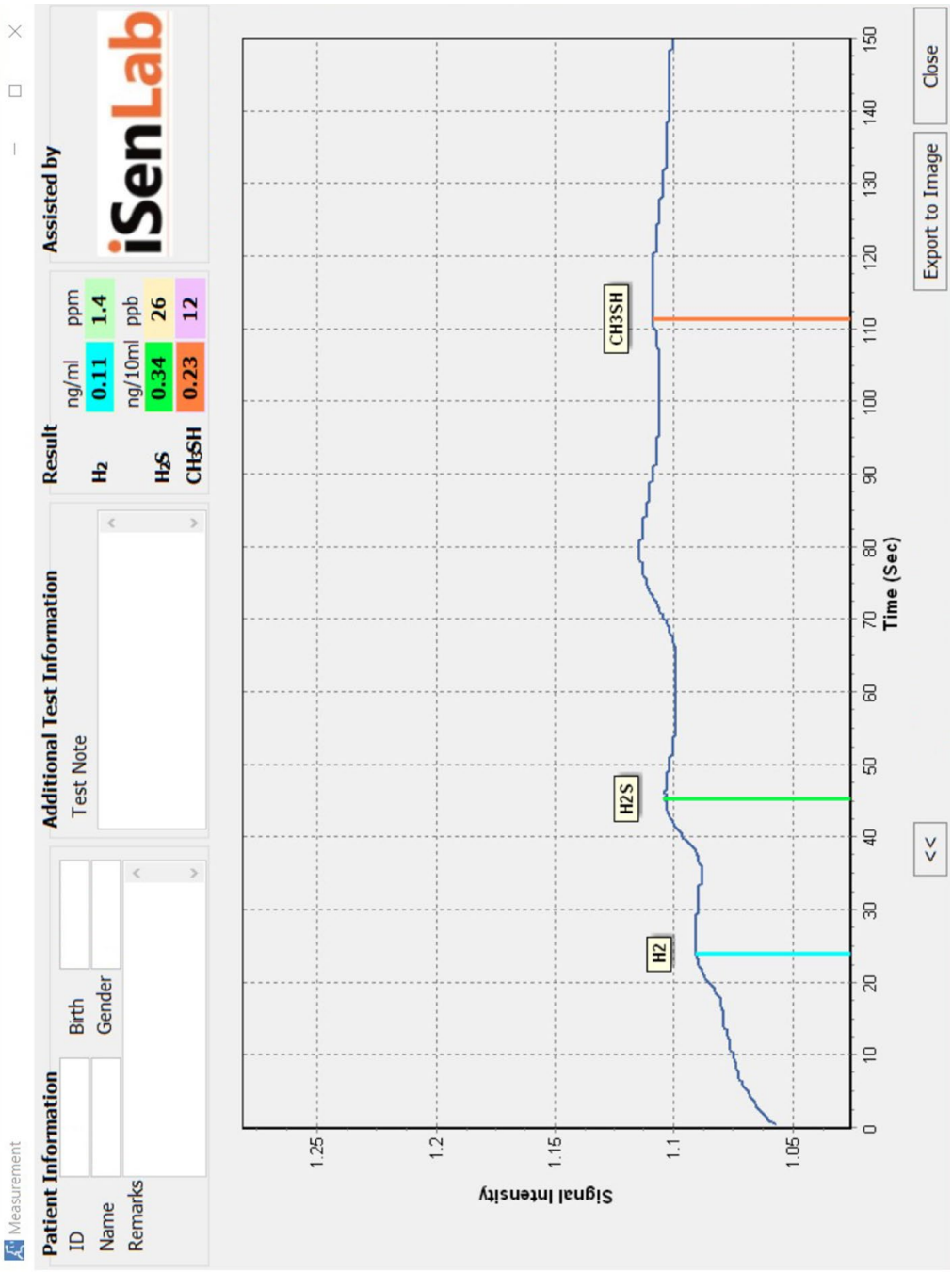


Figure 4. Twin Breasor II

Collection of saliva samples

T-SWAB TRANSPORT™ UTM (NobleBio-sciences, Hwaseong, Republic of Korea) was used to test dental caries and periodontal microbiota in the oral cavity. Among the intraoral areas, the gingiva, cervical, and dental areas of the right maxillary and mandibular molars were rubbed for more than 30 seconds, placed in a collection container containing a preservative solution, stored frozen at -80°C, and deoxyribonucleic acid (DNA) was extracted. Real-time polymerase chain reaction (Real-time PCR) was performed using the PowerCheck Periodontitis Pathogens Multiplex Real-time PCR kit (KogeneBiotech, Seoul, Republic of Korea), and the PowerCheck Dental Caries Pathogens Multiplex Real-time PCR kit was used. (KogeneBiotech, Seoul, Republic of Korea)

In this study, *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, *Tannerella forsythia*, and *Treponema denticola* were classified as periodontal high-risk microbiota, and *Streptococcus mutans*, *Streptococcus obrinus*, *Actinomyces gerencseriae*, *Scardovia wiggsiae*, *Veillonella parvula*, *Candida*, and *Streptococcus sanguinis* were classified as dental caries-risk microbiota.

Participants underwent plaque testing, halitosis testing, and microbiological testing at the baseline visit, and a preliminary survey was administered to their guardians. After clinical evaluation on the baseline date, all participants underwent scaling, and the first toothbrush pre-assigned to each group was distributed. One to three months after the baseline date, we visited for follow-up, received the same evaluation as on the baseline date, and completed a self-report questionnaire about the toothbrush in question.

First, a one-month washout period was held to ensure that the effects of the toothbrush used were dissipated. During this period, the subjects were allowed to freely use toothbrushes, toothpaste, and auxiliary oral hygiene products, and there were no restrictions on the number of times they brushed their teeth. After the washout period and clinical evaluation, additional scaling was performed, and a second pre-assigned toothbrush was distributed. Evaluation was conducted in the same manner 5 and 7 months after the baseline date.

During the period of using Mombrush, the researchers used the Mombrush ProCare application manager mode to extract data such as participants' toothbrushing frequency, score, and areas where teeth were difficult to brush, and provided feedback to participants once a week through notifications within the application. After all studies were completed, study participants completed a self-report questionnaire consisting of questions about their current oral care habits and awareness of smart toothbrushes.

2.4 Statistical analysis

All statistics were performed using SPSS statistical software (SPSS for Windows, version 25; SPSS Inc., Chicago, IL, U.S.A.). The Shapiro-Wilk test was used to test normality, and the independent sample t-test and cross-tabulation were used to analyze the participants' demographics and questionnaires. SHS, QHI, VSC, dental caries, and periodontal microbiota were analyzed by repeated-measures ANOVA followed by Bonferroni test.

All statistics were performed in two-way, and the statistical significance level was set at 0.05.

III. RESULTS

The gender distribution among study participants was 11 men (50%) and 11 women (50%), with an average age of 18.13 ± 6.73 years. Among the participants, 15 individuals (68.2%) had intellectual disabilities, and 7 individuals (31.8%) had developmental disabilities. In addition, in a self-reported survey on current oral care habits and toothbrushing cooperation before the study baseline, the average number of toothbrushing times per day was 2.13 ± 0.56, and the average brushing time per session was 2.52 ± 0.72 minutes. Ten participants (45.5%) reported having received oral health education, while 12 participants (54.5%) indicated they had never received it. The majority of participants (45.5%) responded that 'some help from a guardian is needed' regarding the toothbrushing method. Additionally, the most common level of cooperation in toothbrushing was 'average,' reported by 9 individuals (40.9%), followed by 'cooperative' with 5 people (22.7%) (Table 2.)

Table 2. General characteristics and pre-questionnaire on oral care habits of disabled

Characteristics	Overall (n=22)
Sex	
Male	11 (50)
Female	10 (50)
Age, n (%)	18.13 ± 6.73
Disability	
Intellectual	12 (70.6)
Developmental	5 (29.4)
Average number of teethbrushing per day	2.13 ± 0.56
Average minutes of teethbrushing per brush	2.52 ± 0.72
Have you ever received training on oral hygiene management?	
Yes	10 (45.5)
No	12 (54.5)
What is your typical toothbrushing method?	
Rarely brush teeth	1 (4.5)
Fully assisted by a guardian	7 (31.8)
Partially assisted by a guardian	10 (45.5)
Independently brush teeth	4 (18.2)
How is your toothbrushing cooperation?	
Very uncooperative	1 (4.5)
Uncooperative	4 (18.2)
Neutral	9 (40.9)
Cooperative	5 (22.7)
Very cooperative	3 (13.6)

The gender distribution among the guardians of the study participants was 0 men (0%) and 22 women (100%). The age distribution included one person in their 20s (4.5%), two people in their 30s (9.1%), 11 in their 40s (50%), and eight in their 50s or older (36.4%). Among the guardians, 15 (58.2%) were caring for participants with intellectual disabilities, and seven (31.8%)for those with developmental disabilities.

Regarding the educational background of the guardians, one (4.5%) had less than a high school diploma, four (18.2%) had a high school diploma, two (9.1%) had a junior college degree, 13 (59.1%) had a bachelor's degree, and two (9.1%) had a master's degree or higher. When asked about the time needed to develop proper toothbrushing habits, the majority of caregivers (10, 45.5%) answered 'one month is needed.' In response to whether proper toothbrushing habits are helpful in maintaining healthy teeth, 17 guardians (77.3%) answered ‘strongly agree,’ three (13.6%) answered ‘agree,’ and one (4.5%) answered ‘average.’ Additionally, one guardian (4.5%) answered ‘not very much.’ When asked about their knowledge of smart toothbrushes, four guardians (18.2%) answered ‘I know a little bit,’ and 18 (81.8%) answered ‘I don’t know at all.’ Regarding the willingness to try a smart toothbrush, the largest number of guardians (15, 68.2%) answered 'very much so.' The average frequency of using information technology (IT) devices was 3.35 ± 1.02, and the level of interest in IT devices was 3.30 ± 0.93 (Table 3).

Table 3. General characteristics and pre-questionnaire of smart toothbrush of guardians

Characteristics	Overall (n=22)
Sex	
Male	.
Female	22 (100)
Age	
20s	1 (4.5)
30s	2 (9.1)
40s	11 (50)
50s and above	8 (36.4)
Education	
Below high school graduation	1 (4.5)
High school graduate	4 (18.2)
Associate degree	2 (9.1)
Bachelor degree	13 (59.1)
Master's degree or higher	2 (9.1)
How long do you think you need training to have a good brushing habit?	
1 week	1 (4.5)
1 month	10 (45.5)
3 months	3 (13.6)
6 months	4 (18.2)
1 year or more	4 (18.2)
Do you think that good brushing habits help to maintain healthy teeth?	
Strongly agree	17 (77.3)
Agree	3 (13.6)
Neutral	1 (4.5)
Disagree	.
Strongly disagree	1 (4.5)
Have you ever heard of a smart toothbrush?	
I know well	.
I know a little	4 (18.2)
I don't know	.
I never heard	18 (81.8)

Are you interested in trying out a smart toothbrush?	
Strongly agree	15 (68.2)
Agree	6 (27.3)
Neutral	1 (4.5)
Disagree	.
Strongly disagree	.
Frequency of use of IT devices (1 to 5)	3.35 ± 1.02
Degree of interest in IT devices (1 to 5)	3.30 ± 0.93

In a self-reported survey about current oral care habits and toothbrushing cooperation conducted before the toothbrush was exchanged during study participation, the average number of toothbrushing times per day was 2.14 ± 0.50, and the average brushing time was 2.64 ± 0.58 minutes per session. When using the toothbrush delivered for the study, 8 participants (36.4%) responded that 'all help from the guardian is required,' 6 participants (27.3%) responded that 'some help from the guardian is required,' and 8 participants (36.4%) responded that 'I need some help from the guardian.' Additionally, 8 participants (36.4%) answered ‘myself.’

Regarding the participants' level of cooperation in brushing with the toothbrush delivered for the study, the majority responded as ‘average,’ with 11 people (50%), followed by ‘cooperative,’ with 8 people (36.4%) (Table 4).

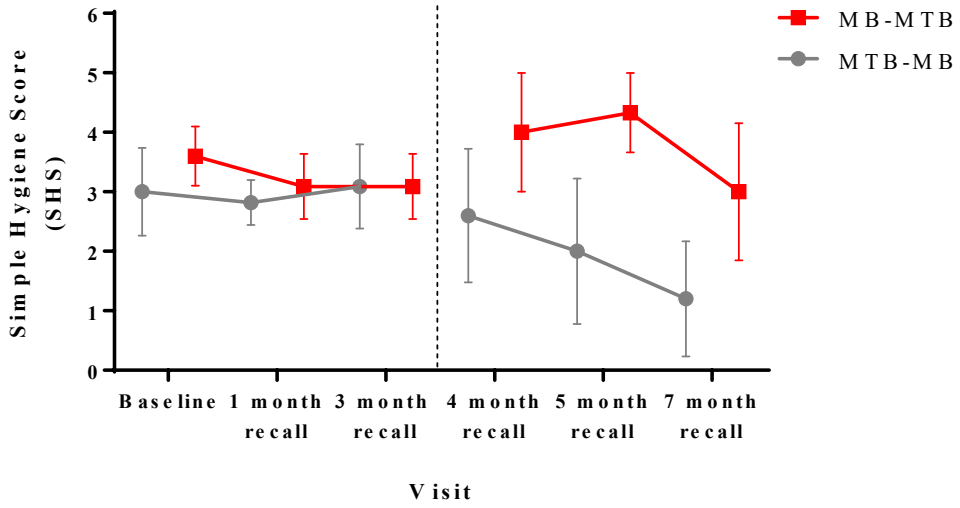
Table 4. General characteristics and interim questionnaire on oral care habits of disabled

Characteristics	Overall (n=22)
Average number of toothbrushing per day	2.14 ± 0.50
Average minutes of toothbrushing per brush	2.64 ± 0.58
What is your typical toothbrushing method?	
Rarely brush teeth	.
Fully assisted by a guardian	8 (36.4)
Partially assisted by a guardian	6 (27.3)
Independently brush teeth	8 (36.4)
How is your toothbrushing cooperation?	
Very uncooperative	1 (4.5)
Uncooperative	.
Neutral	11 (50)
Cooperative	8 (36.4)
Very cooperative	2 (9.1)

The SHS score decreased from 3.60 ± 1.58 points to 3.30 ± 1.77 points before the rest period in the MB-MTB group, and increased from 3.00 ± 2.45 points to 3.09 ± 2.34 points in the MTB-MB group, but there was no significant difference. After the rest period, it was 4.00 ± 1.73 in the MB-MTB group and decreased to 3.00 ± 2.00 at the last visit. In the MTB-MB group, it was 2.60 ± 2.51 and decreased to 1.20 ± 2.16 at the last visit (Figure 5A).

The QHI index decreased from 1.94 ± 1.04 points to 0.84 ± 0.58 points in the MB-MTB group and increased to 1.75 ± 1.38 points in the MTB-MB group, showing a significant difference between the two groups. After the rest period, it was 1.55 ± 0.79 in the MB-MTB group, but it decreased to 1.29 ± 0.76 at 7 month recall. In the MTB-MB group, it was 1.28 ± 0.60, but decreased to 1.06 ± 0.74 at 7-month recall (Figure 5B).

(A)



(B)

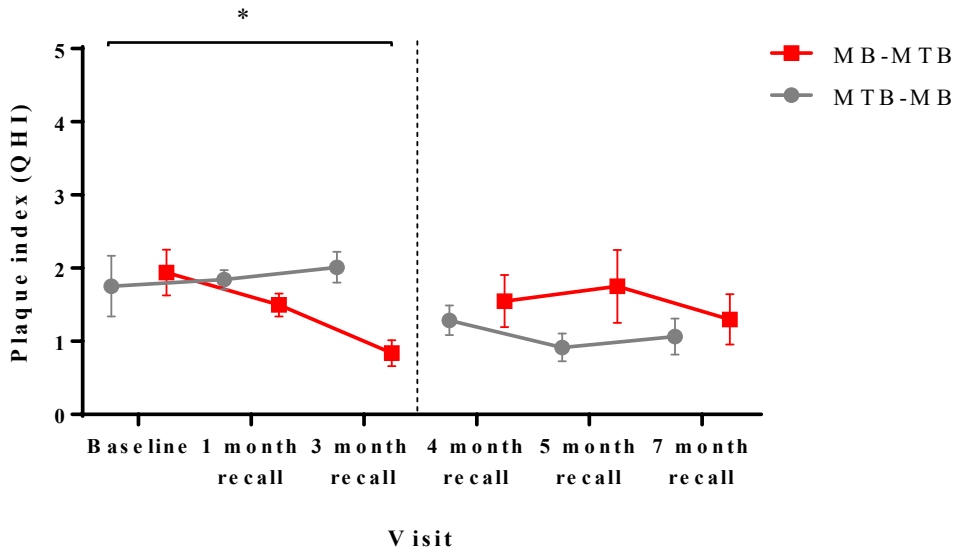


Figure 5. Plaque test according to toothbrush type A; SHS, B; QHI

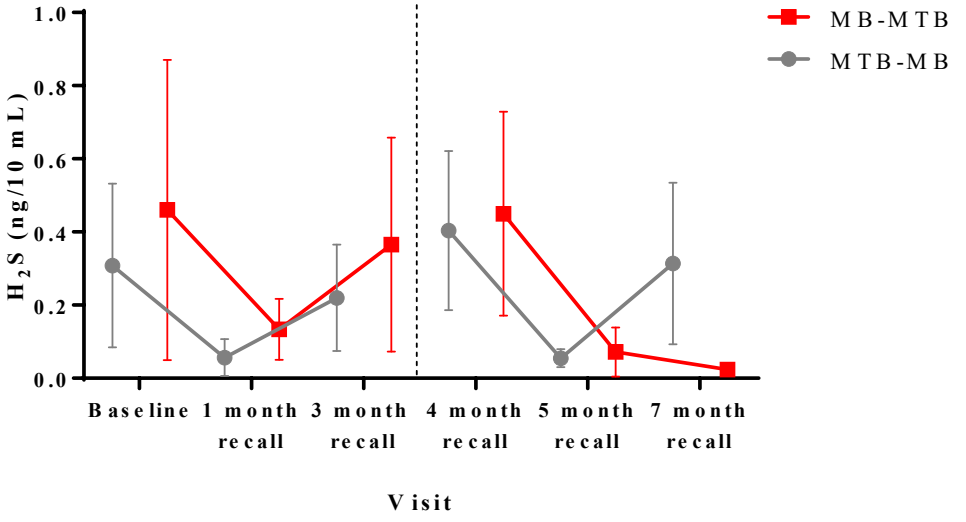
H_2S levels in the MB-MTB group decreased from 0.46 ± 1.36 at baseline to 0.13 ± 0.28 after 1 month and then increased to 0.37 ± 0.97 after 3 months. After a one-month pause, it continued to decrease to 0.45 ± 0.62 in 4 month recall, 0.07 ± 0.14 in 5 month recall, and 0.02 ± 0.03 in the final 7 month recall. The MTB-MB group also decreased from 0.31 ± 0.74 at baseline to 0.06 ± 0.17 after 1 month. After 3 months of decline, it increased to 0.22 ± 0.48. After a one-month rest period, the 4 month recall was 0.40 ± 0.68, the 5 month recall was 0.05 ± 0.07, and the last 7 month recall was 0.31 ± 0.69 (Figure 6A).

CH_3SH levels also decreased in the MB-MTB group from 0.07 ± 0.22 at baseline to 0.02 ± 0.08 after 1 month and then increased to 0.22 ± 0.49 after 3 months. After a one-month rest period, it was 0.37 ± 0.68 at 4 month recall and 0.10 ± 0.21 at 5 month recall. The last 7 month recall was 0.10 ± 0.15.

The MTB-MB group also decreased from 0.09 ± 0.16 at baseline to 0.06 ± 0.10 after 1 month. After 3 months of decline, it increased to 0.14 ± 0.27. After a one-month rest period, the 4 month recall was 0.27 ± 0.38, the 5 month recall was 0.02 ± 0.03, and the last 7 month recall was 0.10 ± 0.13 (Figure 6B).

H_2S and CH_3SH levels decreased after 1 month in both groups but increased after 3 months, with no significant differences over time.

(A)



(B)

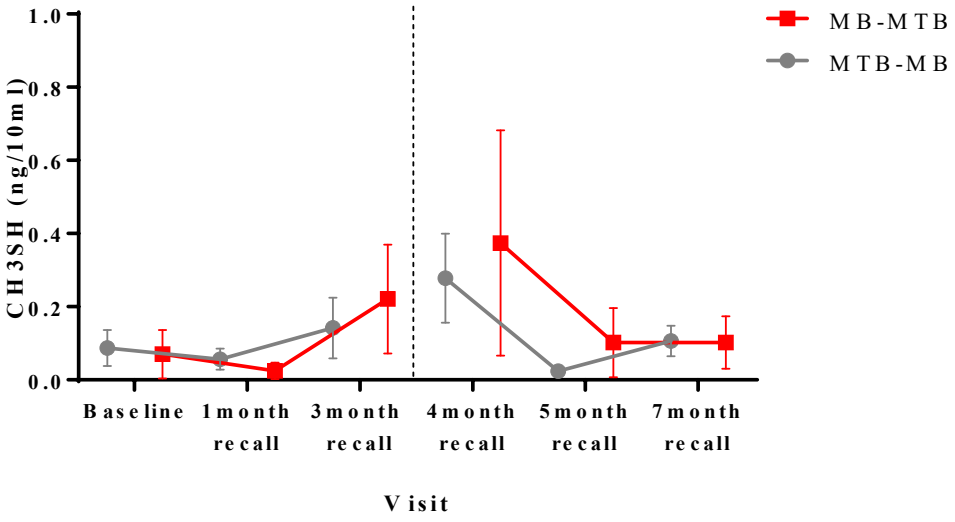
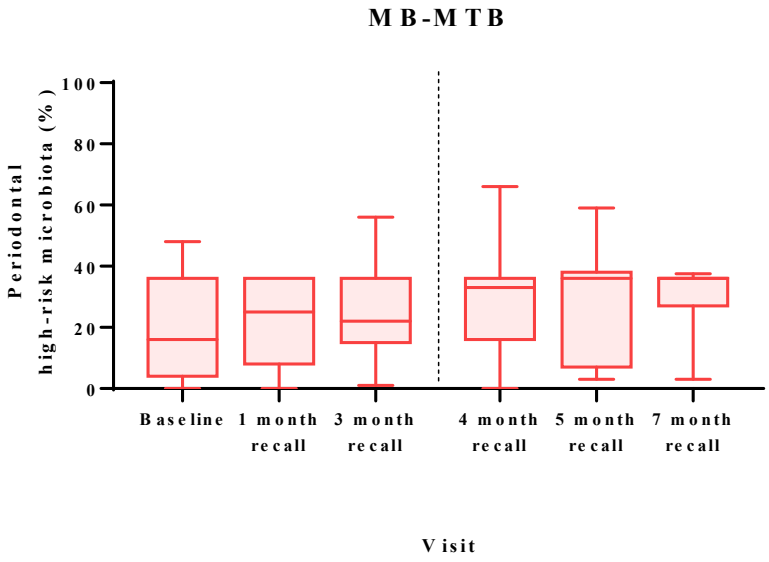


Figure 6. Halitosis test according to toothbrush type A; H_2S, B; CH_3SH

Periodontal high-risk microorganisms increased from 20.55 ± 17.89% to 26.45 ± 15.18% in the MB-MTB group from baseline to 3 months later and then slightly increased to 31.36 ± 12.15% at the last visit. The MTB-MB group decreased from 25.36 ± 21.96% to 23.27 ± 20.19%, and the recall at the last 7 months, was 25.45±15.45%. However, no significant differences emerged within the two groups over time (Figure 7A, B).

(A)



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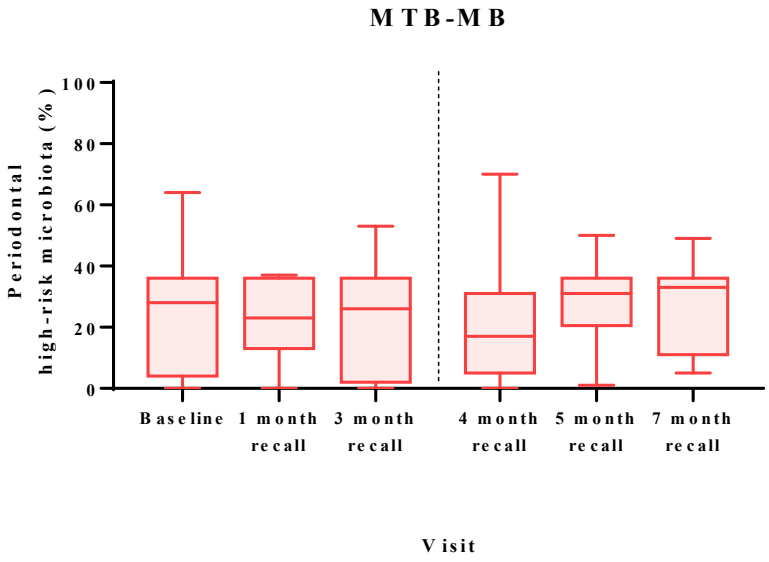
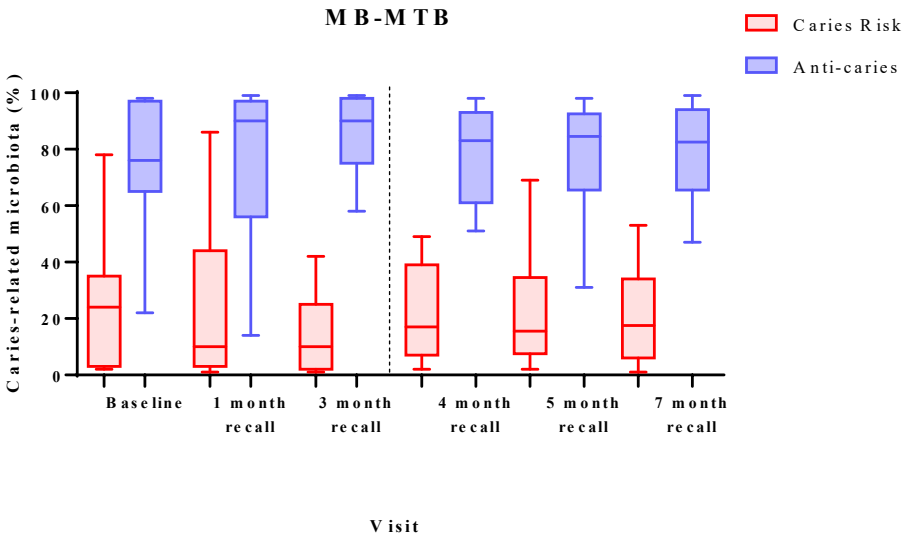


Figure 7. Changes in periodontal high-risk microbiota according to toothbrush type

In the change in the ratio of dental caries risk microorganisms and inhibitory microorganisms in the MB-MTB group, the ratios of dental caries risk microorganisms and inhibitory microorganisms as of the reference date were 23.73% and 76.27%, respectively. After 3 months, the proportion of dental caries risk microorganisms decreased to 13.73%, while the number of inhibitory microorganisms increased to 86.27%, and at the last visit, dental caries risk microorganisms were 19.50% and inhibitory microorganisms were 80.50% (Figure 8A).

Additionally, at baseline, the MTB-MB group recorded 41.18% and 58.82%, respectively. After 3 months, the dental caries risk microorganism group increased to 37.36%, and the dental caries inhibitory microorganism group decreased to 62.64%. At the last visit, it was 30.18% and 69.82%. There was no significant difference in both groups (Figure 8B).

(A)



(B)

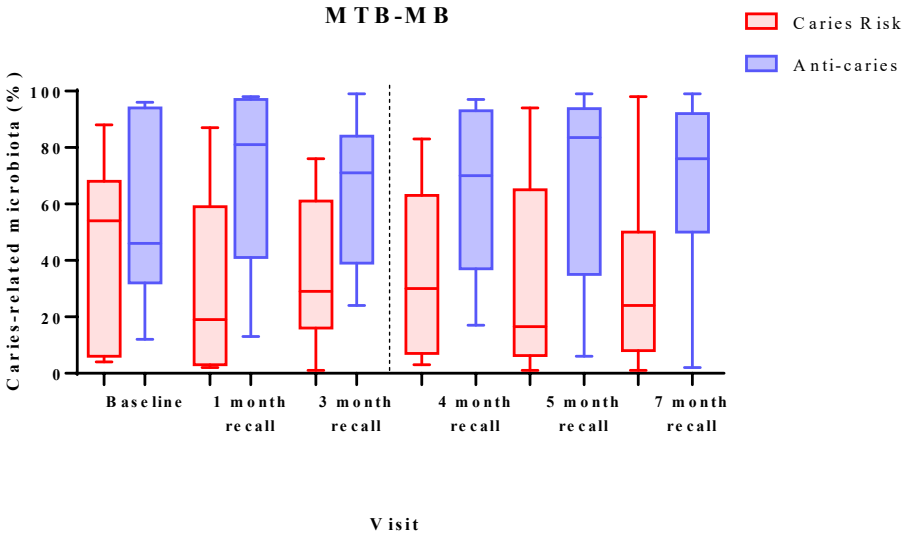


Figure 8. Changes in dental caries microbiota according to toothbrush type

In a survey conducted after the end of the study, the average number of toothbrushing times per day was 2.09 ± 0.56, and the average brushing time per session was 2.77 ± 0.98 minutes. When using the toothbrush delivered for the study, 5 participants (22.7%) responded that 'all help from the guardian is required,' 9 participants (40.9%) answered 'some help from the guardian is required,' and 8 participants (36.4%) reported 'self-help in the toothbrush method.' Additionally, 8 participants (36.4%) answered ‘myself.’

Regarding the participants' level of cooperation in brushing with the toothbrush delivered for the study, the majority responded as ‘cooperative,’ with 12 people (54.5%), followed by ‘very cooperative,’ with 6 people (27.3%) (Table 5).

Table 5. General characteristics and post-questionnaire on oral care habits of disabled

Characteristics	Overall (n=22)
Average number of toothbrushing per day	2.09 ± 0.56
Average minutes of toothbrushing per brush	2.77 ± 0.98
What is your typical toothbrushing method?	
Rarely brush teeth	.
Fully assisted by a guardian	5 (22.7)
Partially assisted by a guardian	9 (40.9)
Independently brush teeth	8 (36.4)
How is your toothbrushing cooperation?	
Very uncooperative	1 (4.5)
Uncooperative	.
Neutral	3 (13.6)
Cooperative	12 (54.5)
Very cooperative	6 (27.3)

As a result of comparing the number of toothbrushing (day), brushing time (minutes), and toothbrushing cooperation of each group in a survey conducted during the study period, the number of toothbrushing significantly increased to -0.81 ± 0.60 in the Baseline - 3 month recall when MB was used in the MB-MTB group (Table 6). After changing with MTB, there was a significant decrease from 3 month recall - 7-month recall from 1.45 ± 0.68. A significant decrease in baseline - 7 month recall was found to result in 0.63 ± 0.67. When using MTB in the MTB-MB group, the number of toothbrushing increased to -0.18 ± 0.40, but there was no significant difference. In addition, even after changing with MB, there was an increase to -0.54 ± 0.93, but there was no significant difference. A significant increase in baseline - 7 month recall was found to result in -0.72 ± 0.90.

Brushing time showed a significant increase of -0.81 ± 1.16 when MB was used in the MB-MTB group. After changing with MTB, there was a significant decrease to 1.09 ± 0.70. There was a decrease from baseline - 7 month recall of 0.27 ± 1.19, but no significant difference. When using MTB in the MTB-MB group, brushing time decreased to 0.45 ± 0.82, but there was no significant difference. Additionally, after changing with MB, there was a significant increase to -0.90 ± 1.04. The result was an increase from baseline - 7 month recall to -0.45 ± 0.93, but there was no significant difference.

Toothbrushing cooperation showed a significant increase to -1.09 ± 0.94 when MB was used in the MB-MTB group. After changing with MTB, the significantly decreased to 1.00 ± 1.00. The baseline - 7 month recall was -0.91 ± 0.94, but no significant difference. When using MTB in the MTB-MB group, cooperation increased to -0.27 ± 0.90, but there was no significant difference. Also, after changing with MB, there was an increase to -0.90 ± 0.70, but there was no significant difference. A significant increase in baseline - 7 month recall was found to result in -1.18 ± 0.98.

Table 6. Number of toothbrushing, time, and cooperation according to visit period for each group

	Baseline - 3 month recall		**3 month recall - 7 month recall**		**Baseline - 7 month recall**	
	Mean (SD)	*P*	Mean (SD)	*P*	Mean (SD)	*P*
Number of toothbrushing (day)						
MB–MTB	-0.81±0.60	**0.007***	1.45±0.68	**0.002***	0.63±0.67	**0.020***
MTB–MB	-0.18±0.40	0.157	-0.54±0.93	0.084	-0.72±0.90	**0.038***
Brushing time (Minutes)						
MB–MTB	-0.81±1.16	**0.047***	1.09±0.70	**0.006***	0.27±1.19	0.453
MTB–MB	0.45±0.82	0.096	-0.90±1.04	**0.026***	-0.45±0.93	0.132
Toothbrushing Cooperation						
MB–MTB	-1.09±0.94	**0.012***	1.00±1.00	**0.018***	-0.91±0.94	0.785
MTB–MB	-0.27±0.90	0.317	-0.90±0.70	0.206	-1.18±0.98	**0.010***

IV. DISCUSSION

The development of smart devices plays a crucial role in facilitating healthcare practices for individuals in need (Plackett et al., 2017). New approaches to education, utilizing mobile devices and tablets, are interesting and engaging methods for individuals with disabilities. (Lancioni et al., 2022; Lancioni et al., 2017). Smart toothbrushes stand out among the array of smart devices that have emerged due to recent technological advancements. Distinguishable from conventional manual toothbrushes, they are digital toothbrushes that establish a Bluetooth connection with a smartphone.

These devices help participants develop good toothbrushing habits by providing real-time monitoring and brushing instructions (Lancioni et al., 2022; Lancioni et al., 2017). Therefore, this study aimed to establish habits so that participants with intellectual/developmental disabilities could brush their teeth correctly and to assess the impact on oral hygiene management.

The results of this study showed that the SHS score did not exhibit a significant difference in both groups but decreased compared to the first visit. The QHI test revealed a significant difference between the two groups, decreasing from 1.94 ± 1.04 points to 0.84 ± 0.58 points in the MB-MTB group and increasing to 1.75 ± 1.38 points in the MTB-MB group.

In the halitosis test, both the MB-MTB and MTB-MB groups exhibited a decrease in H_2S and CH_3SH during the 1-month recall period. However, they

showed an increase in H_2S and CH_3SH during the 3 month recall. The 5 month recall in H_2S decreased, similar to the 1 month recall. However, it increased in the MTB-MB group and decreased in the MB-MTB group. Additionally, CH_3SH decreased in the 5 month recall and increased in the 7 month recall in both groups. Although this result was not statistically significant, it suggests that as the recall period lengthened, participants became less engaged and neglected oral hygiene management.

However, accurately capturing the SHS test depended on the participant's cooperation during Q-ray filming. The SHS score is sensitive to the surrounding lighting environment, and even a small amount of light can create the appearance of plaque, making it challenging to determine an accurate score.

As shown in the results of this study, in terms of oral hygiene management ability, both groups scored lower than the reference point in the test conducted at the last visit (7 month recall). Therefore, it is believed that the use of smart toothbrushes is effective in improving the oral hygiene management ability of people with disabilities. Repetitive video playback learning appears to be effective for individuals with disabilities. In addition, it is difficult to determine whether the score is accurate because only the front view was taken rather than a 5-segment shot. However, the QHI test could be administered equally to all participants regardless of their cooperation. Unlike the SHS test, the score does

not change depending on ambient lighting; therefore, it is considered to be an accurate score.

The crossover method used in this study means that each participant served as a subject and a control. This method has the advantage of reducing the total number of study subjects, thereby reducing the variation among participants. This research design method can increase test power by reducing the number of tests (Silva et al., 2020). Additionally, the different orders of the two groups can be compared through a cross-sectional design study (Schensul et al., 2019). However, since the study period is extended as both the experimental and control groups are applied through a cross-sectional study, it also has the disadvantage of increasing dropout rates.

In this study, Mambrush demonstrated more significant results in the 3 months preceding the rest period. Following the rest period, both groups recorded scores lower than the baseline. Despite the MB-MTB group using a manual toothbrush in the final phase, it is presumed that the positive impact persisted from the previous Mambrush usage, contributing to the favorable scores. Therefore, it is suggested that continuous use of Mambrush may aid in oral hygiene practices.

In a cross-sectional study on toothbrushes conducted on people with Down syndrome, they were divided into a regular toothbrush group and an electric

toothbrush group. No significant difference was found between the two groups, but the amount of plaque was significantly reduced (Silva et al., 2020).

A study conducted in Japan reported that people with disabilities experience more tooth loss at a younger age than the general population (Nonoyama et al., 2022), indicating the need for oral care intervention at an earlier age for individuals with disabilities. Another study reported that children's use of smart toothbrushes was effective in teaching correct toothbrushing and reducing plaque (Lee et al., 2023).

Another study conducted on guardians and caregivers in an elderly care home showed a significant decrease in plaque and bleeding index during the period when participants were provided with oral care using a remote-monitored toothbrush. However, in the follow-up period after the end of the study, plaque and bleeding index increased again. The bleeding index showed a significant increase (Wagner et al., 2021). The results of the study conducted on these vulnerable participants suggest that oral health care can be improved if experts provide continuous oral care intervention to participants and their guardians or caregivers.

The Mombrush used in this study, unlike other smart toothbrushes on the market, had the advantage of allowing oral hygiene management experts, such as dentists or dental hygienists, to check and provide feedback on participants' oral care results in real-time through the application. Individual compliance with

the use of a smart toothbrush is important, but compliance can only be improved with expert intervention. If there is expert feedback or intervention on oral care, as in the study conducted in the nursing home above, the participant's oral care ability or guardian's level of compliance can be improved (Ghaffari et al., 2018).

The first limitation of this study is that the video playback speed of the application was fast, making it difficult for participants with slow finger movements. Second, when recruiting participants, subdivisions according to the degree of disability were not used; therefore, the study was not conducted according to the characteristics of the participants.

In future, it will be necessary to conduct research on more people with intellectual or developmental disabilities. Groups should be subdivided according to the degree of disability of the recruited participants, and oral care methods explored, so that progress can be made according to the characteristics of the participants. In addition, it seems necessary to investigate participants' satisfaction and compliance by adding a function that can adjust the speed of the video played in the application to suit the level of the participant using it.

V. CONCLUSION

This study demonstrated the positive impact of using a smart toothbrush on the oral hygiene of people with intellectual and developmental disabilities. These skills can help participants manage their oral hygiene independently, which can ultimately improve their quality of life. Smart toothbrushes are expected to emerge as an important tool in oral hygiene management in the future, but continued interest will be needed to ensure that people with intellectual or developmental disabilities continue to be interested in oral care.

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국문요약

스마트 칫솔을 활용한 지적/발달 장애인의 원격 구강 위생 관리

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목적

지적 및 발달 장애를 가진 개인들은 일상적인 구강 위생을 유지하는 데 다른 개인들보다 더 큰 어려움을 겪는다. 모바일 기술의 발전은 건강 관리 실천에 도움을 주고 있으며, 이러한 기기들 중 스마트 칫솔은 사용자의 칫솔질 데이터를 수집하고 분석하여 올바른 치과 관리를 제공한다. 스마트 칫솔은 사용자의 동작을 감지하고 개개인에게 적절한 피드백을 제공하여 습관 교정을 유도한다.

본 연구의 목적은 스마트 칫솔이 지적 또는 발달 장애를 가진 개인들의 전반적인 구강 위생 관리에 미치는 영향을 평가하며, 구강 건강 관리에 도움이 되는지를 평가하는 것이다.

재료 및 방법

참여자 수는 각 그룹에 13 명으로 총 26 명으로, 최종적으로 26 명의 참여자 중 2 명이 동의 철회하고 2 명이 추적 실패하여 총 22 명이 연구를 완료했다. 연구에서 참여자들은 먼저 Mombrush(MB)를 사용한 후 수동 칫솔(MTB)을 사용한 그룹(MB-MTB 그룹)과 MTB 를 사용한 후 MB 를 사용한 그룹(MTB-MB 그룹)으로 나뉘었으며, 한 달의 휴지기가 있었다.

방문 시기는 기준선, 1 달 후 검사, 3 달 후 검사, 1 달 휴식 기간, 기준선 4 달 후 검사, 5 달 후 검사 및 7 달 후 검사 였다. 각 방문 시에는 simple hygiene score (SHS) 및 Quigley-Hein Plaque Index (QHI) 테스트가 실시되었고, 구취가 측정되고 미생물이 수집되었다.

결과

SHS 점수는 MTB-MB 그룹에서 baseline 3.00 ± 2.45 점에서, 연구가 종료된 시점의 점수는 1.20 ± 2.16 점으로 감소했다. MB-MTB 그룹에서는 점수가 3.6 ± 1.57 점에서 3.6 ± 1.57 점으로 감소하였고, baseline 에서는 3.00 ± 2.00 점이나 변화가 크지 않았으며, QHI 지수는 MB-MTB 그룹의 baseline 1.94 ± 1.03 점에서 연구 종료 시 1.29 ± 0.76 점으로 감소하였다.

MTB-MB 그룹의 baseline 1.75 ± 1.37 점에서 연구가 종료 시 1.06 ± 0.74 점으로 감소하였으며, 칫솔 교체 전 두 그룹 사이에는 유의한 차이가 있었다. MB-MTB 그룹의 baseline 에서 H2S 수치는 0.46 ± 1.36 이었으나

연구 종료 시에는 0.02 ± 0.03 으로 감소하였다. MTB-MB 그룹의 baseline 은 0.30 ± 0.74 였고, 연구 종료 시에는 0.31 ± 0.69 로 증가했다. MB-MTB 그룹의 CH3SH 수치는 baseline 에서 0.07 ± 0.21 에서 연구 종료 시 0.10 ± 0.15 이었으며, MTB-MB 그룹의 경우 baseline 에서 0.87 ± 0.16 에서 연구 종료 시 0.10 ± 0.13 였다.

H2S 와 CH3SH 수준 모두 시간이 지남에 따라 두 그룹 모두 시간의 흐름에 따른 유의미한 차이는 없었다.

결론

이 연구는 교차 연구로 진행되어 참가자들이 모두 대조군과 실험군을 참여하였고, 휴지기 전 두 그룹의 비교에서는 Mombrush 를 사용할 때가 수동 칫솔을 사용할 때 보다 구강 위생 지수에 영향을 보였다. 휴지기 이후 두 그룹 모두 구강 위생 지수가 감소한 결과를 보였지만, MB-MTB 그룹이 조금 더 감소한 결과를 보였으며, MB-MTB 그룹도 구강 위생 지수에 영향을 보였다. 이것은 MB-MTB 그룹에서 칫솔 교체 이전에 칫솔질 교육을 받은 기억이 남아있어 구강 위생 관리에 더 도움이 되었다고 생각 된다.

본 연구의 결과로 지적이나 발달 장애를 가진 개인들의 구강 위생에 스마트 칫솔이 긍정적인 영향을 미친다는 것을 보여주었다. 그러나 긍정적

결과를 유지하기 위해 지적이나 발달 장애를 가진 개인들에게 구강 관리에 대한 지속적인 관심을 유도할 필요가 있다고 생각된다.

핵심되는 말: 지적 장애, 발달 장애, 스마트 칫솔, 원격 구강관리