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Original Article

A mobile augmented reality-integrated oral health education for community dwelling older adults: A pilot study

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Background/purpose: Providing oral healthcare education can be an optimal strategy for imparting knowledge and developing self-care skills for older adults to enhance their oral health conditions. However, traditional passive lecture-based education programs have several limitations. Integrating mobile augmented reality (MAR) into oral health education can potentially enhance the effectiveness of the education by mitigating those limitations. The objectives of this study are to develop and evaluate the effectiveness of MAR-integrated oral health education. The objectives of this study were to develop and evaluate the effectiveness of MAR-integrated oral health education.

Materials and methods: Twenty-four older adults from community dwellings participated in this study. The participants received MAR-integrated oral health education once at activity centers. Self-report questionnaires were utilized to assess oral healthcare-related knowledge and self-efficacy, and the usability score of the MAR system. The assessment was conducted before and after the educational program. Data were statistically analyzed using descriptive statistics and paired-t test.

Results: The mean scores of oral healthcare-related knowledge and self-efficacy showed a significant increase after the educational program, with *P*-values of <0.001 and 0.002, respectively. A majority of the participants exhibited a lack of knowledge and self-efficacy regarding the proper selection of toothpaste and interdental brushes. However, there was an improvement after the intervention. The usability score of the system was lower than the average level.

Conclusion: MAR-integrated oral health education effectively increases oral health-related

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knowledge and self-efficacy among community dwelling older adults. Still, the usability of the MAR system needs to be improved. Further investigation of long-term effects and clinical outcomes, and the inclusion of comparative groups are recommended for the future study.

Introduction

Aging is an inevitable demographic trend of the 21st century. More than one in eight people worldwide will be 65 or older by 2030.[1] In Taiwan, the population already consists of 14.1% older individuals as of 2018, and the country is projected to become a super-aged society by 2025.[2] This demographic shift highlights the importance of addressing oral health concerns, as they can lead to general health problems and negatively impact well-being and quality of life.[3] Older adult patients who receive proper oral healthcare may have fewer chances of developing fever and respiratory infections.[4,5]

To improve oral health conditions among older people, oral healthcare education could be the optimal measure to provide knowledge and develop self-care skills for elderly people to improve their oral health conditions. Learning how to choose appropriate oral care products and understand their usage is one of the fundamental skills to achieve proper oral hygiene. However, the traditional passive lecture-based educational program may not be sufficiently effective.[6] Previous studies attempted to improve the effectiveness of oral education for older persons by modifying learning materials[7,8] and integrating digital technology.[9,10] Nonetheless, to date, there has been no study that develops and investigates an augmented reality (AR) system to promote oral education for older adults.

Augmented reality (AR) allows the integration of a virtual elements with a real-world situation.[11,12] This technology enables the superimposition of digital files like images, animations, videos, and 3D models onto the real environment, facilitating increased user interactions. There are many ways available to experience AR technology. Not only wearable headsets and smart glasses but also AR-integrated applications on handheld devices such as smartphones or tablet devices are able to access and apply AR. Mobile Augmented Reality (MAR) specifically refers to AR accessible through portable devices used in daily life.[11] MAR is suited to "ubiquitous learning" concept, which means learners can learn all the time, wherever they are, and when they need to.[13]

A recent systematic review conducted in 2022 showed that the usage of AR improved knowledge retention and patient satisfaction.[14] AR has been implemented in various aspects of dental education. Several publications have explored the potential of using AR to deliver knowledge[15–19] and skills[18,20–24] in Dentistry. However, MAR for oral health education has not been studied yet. This pilot study aimed to develop and evaluate the effectiveness of MAR-integrated oral health education for older adults in community dwellings.

Material and methods

Participants recruitment

The sample size was determined using a statistical analysis software for Windows (GPower, v3.1.9.7; Universität Düsseldorf, Germany) to test the differences in means for two dependent groups. With a significance of 0.05, an effect size of 0.80[7] and a power of 0.80, the minimum sample size was calculated to be 15.

Ethical approval was granted by the institutional review board (IRB) of National Yang Ming Chiao Tung University (Approval number: YM111157E). Before signing the informed consent, all participants were explained the significance and content of this study. The study included a total of 24 independent older adults (aged 65 or older) who were selected from two activity centers with similar backgrounds in oral health education located in the Beitou district of Taipei City, Taiwan. The inclusion criteria were the older adults who are able to use a smartphone, have no communication problems, and are able to read and understand traditional Chinese.

MAR-integrated oral health education program

The oral health educational program was developed based on the content of a conventional lecture-based oral health educational program provided by dental hygienists in Taiwan. To address the advantages and limitations of the educational program, interviews were conducted with dental hygienists and dentists. The main limitations were about the selection and usage of oral care products. In this study, we aimed to overcome those limitations by using an augmented reality system (Fig. 1) with 3D virtual models (Fig. 2). The figures and 3D models were imported into the MAR software (MAKAR; Taipei, Taiwan) to create an educational project. An image recognition algorithm was utilized to access the contents. The MAR application (MAKAR; Taipei, Taiwan) served as an educational platform to deliver teaching content to the participants. This software could be installed on mobile phones and tablet devices with iOS or Android system, requiring an internet connection for downloading and usage. All learning materials were designed according to the principle of Gerogogy.[25] The modules, content and educational tools in the educational program were described in Table 1.

The educational program was delivered to the participants once at the activity centers. The process of delivery included demonstrating how to use the MAR system and allowing the participants to try it themselves by using

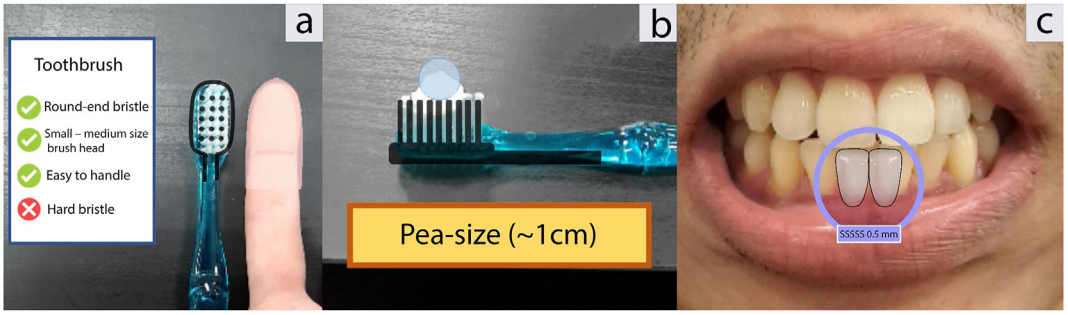

Figure 1 The applications of AR for an oral health educational program (English version). (a) The application of AR for the suitable toothbrush selection. (b) The application of AR for the suitable toothpaste usage. (c) The application of AR for the suitable interdental brush size selection.

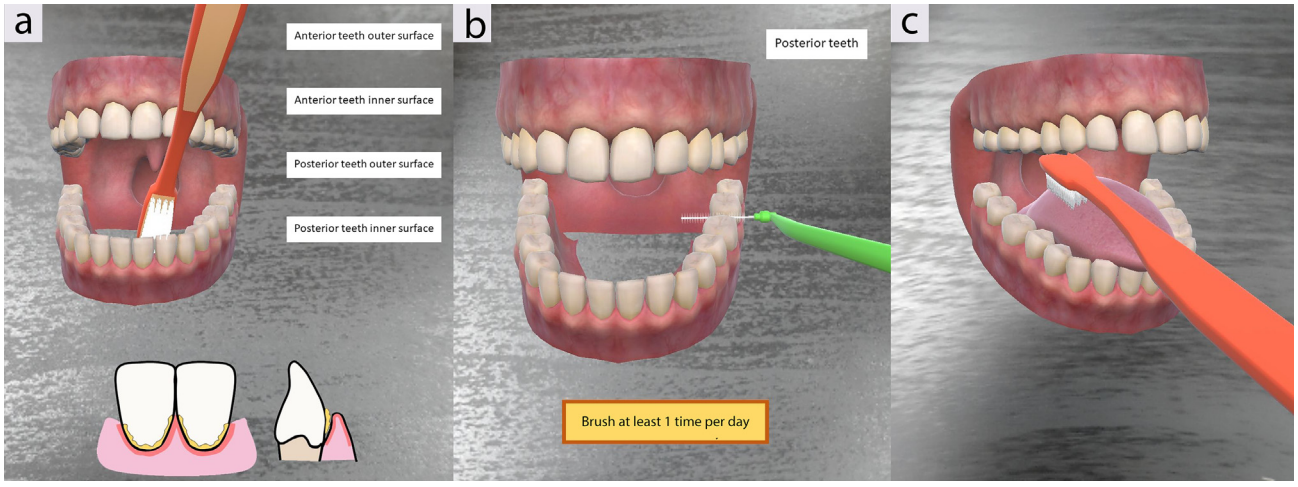

Figure 2 The applications of 3D virtual models for an oral health educational program (English version). (a) The application of 3D virtual models for the suitable toothbrushing. (b) The application of 3D virtual models for the suitable interdental brush usage. (c) The application of 3D virtual models for the suitable tongue cleaning.

Table 1 Modules, content, and educational tools in MAR-integrated oral health education.

Module	Content	Educational tool
Toothbrush	Proper selection	- Augmented reality - 2D images
	Proper usage	- Animated 3D models - 2D images
Interdental brush	Proper selection	- Augmented reality - 2D images
	Proper usage	- Animated 3D models
Denture	Proper care	- Text
Toothpaste	Proper selection	- Text
	Proper usage	- Augmented reality - 2D images
Tongue cleaning	Proper selection	- Text
	Proper usage	- Animated 3D models
Mouthwash	Proper selection	- Text
	Proper usage	- Text

2D and 3D referred to two-dimensional and three-dimensional, respectively.

smartphones or tablet devices. The schematic diagram illustrating the usage of the system by the participants was shown in Fig. 3. Self-reported questionnaires were employed to assess oral healthcare-related knowledge, self-efficacy, and the usability score of the MAR system before and immediately after the intervention. On average, around 45 min was spent on the educational program and 15 min for outcomes assessment.

Outcome measurements

Oral healthcare-related knowledge

Fifteen statements were used to assess participants' oral healthcare-related knowledge. The possible response options include "True", "False", and "Don't know". A correct answer scores 1, while an incorrect answer and "Don't know" responses score 0. A higher score indicated a greater degree of oral healthcare-related knowledge, with a possible score of 0–15. The question statements were presented in traditional Chinese. The content validity was evaluated by an expert panel consisting of a professor

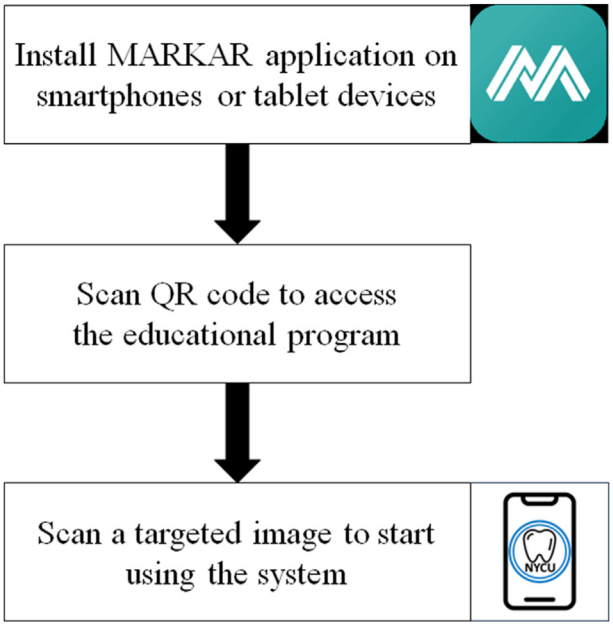

Figure 3 The schematic diagram illustrating the usage of the system by the participants.

specializing in dental education and an assistant professor who has experience in providing oral health education in community settings. All questions were reviewed and modified until reached an item-objective congruence (IOC) score of 1. The Kuder-Richardson 20 reliability coefficient for the scale was 0.69. An English version of the oral healthcare-related knowledge questionnaire is presented in Table 2.

Table 2 An English version of oral healthcare-related knowledge questionnaire.

	True	Don't know	False
K1. A small head toothbrush can brush posterior teeth easily.			
K2. The harder toothbrush bristles, the more thoroughly the teeth can be cleaned.			
K3. The gum line should be emphasized during teeth brushing.			
K4. A toothbrush needs to be replaced every 3 months.			
K5. An interdental brush is used to remove the dental plaque that forms between teeth.			
K6. Any size of interdental brush can clean interdental space properly.			
K7. Fluoride toothpaste with a fluoride content of 1000 ppm or higher can prevent tooth decay.			
K8. Mint, cooling flavors, and high foaming toothpaste are suitable for the elderly.			
K9. Whitening toothpaste is suitable for the elderly.			
K10. Alcohol contained mouthwash is suitable for the elderly.			
K11. Dentures should be cleaned with toothpaste every day.			
K12. Tongue cleaning is necessary for oral care.			
K13. Toothbrushes can be used for tongue cleaning.			
K14. Tongue should be brushed from front to back.			
K15. Edentulous people still require oral care.			

Oral healthcare-related self-efficacy

To assess participants' oral healthcare-related self-efficacy, seven statements were employed. The question statements were presented in traditional Chinese. Each item was scored on a 5-point Likert-type scale ranging from 1, "strongly disagree", to 5, "strongly agree". A higher score indicated a greater degree of self-efficacy, with a possible score of 7–35. The content validity was evaluated by the same expert panel. The Cronbach's alpha for the scale was 0.71. Table 3 shows an English version of oral healthcare-related self-efficacy questionnaire.

Traditional Chinese System Usability Scale (C-SUS)

The System Usability Scale (SUS) questionnaire is a commonly used tool for evaluating usability. In this study, we employed the traditional Chinese version of the System Usability Scale (C-SUS) from the study conducted by Feng-Ru Sheu, Hui-Jung Fu, and Meilun Shih in 2017.[26] Ten statements were used with a 5-point Likert-type scale ranging from 1, strongly disagree, to 5, strongly agree. The scores obtained were then assigned a rating using a curved grading scale (CGS).[27]

Statistical analysis

The acquired data were analyzed using a statistical software program (SPSS Statistics for windows, v21.0; IBM, New York, NY, USA) and Microsoft Excel (Microsoft Excel for Microsoft 365 MSO, v.2305; Microsoft, Redmond, WA, USA). Mean scores for oral health-related knowledge and self-efficacy before and after the intervention were compared using paired *t*-test, with the significance level set at $P = 0.050$. Descriptive statistics were used to analyze the outcomes for each question and the C-SUS score.

Results

The general characteristics of the participants are described in Table 4. The age of the participants ranged

Table 3 An English version of oral healthcare-related self-efficacy questionnaire.

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
S1. Choosing a suitable toothbrush is difficult for me.					
S2. Choosing a suitable toothpaste is difficult for me.					
S3. Choosing a suitable interdental brush is difficult for me.					
S4. I think I can clean my teeth with a toothbrush in a correct way.					
S5. I think I can clean my teeth with an interdental brush in a correct way.					
S6. I think I can clean my tongue in a correct way.					
S7. I think I can clean my denture in a correct way.					

Table 4 General characteristics of the participants.

Characteristic	Participants (n = 24)
Sex	
Male	20.83% (5)
Female	79.17% (19)
Age	75.21 ± 8.21 years
Education level	
Lower than high school	41.67% (10)
High school or higher	58.33% (14)
Smoking	8.3% (2)
Drinking alcohol	12.5% (3)
Dental visit	
Every 6 months	41.67% (10)
Once a year	12.50% (3)
Less than once a year	45.83% (11)

Data are presented as percentage and (n) for the number of participants, except an age category which was presented as mean ± standard deviation.

Table 5 Findings of paired *t*-test on mean values of oral health-related knowledge and self-efficacy.

Outcome	Pre-intervention (mean ± SD)	Post-intervention (mean ± SD)	*P-value*
Knowledge	9.67 ± 2.68	11.92 ± 2.72	<0.001[a]
Self-efficacy	22.67 ± 5.02	26.58 ± 5.63	0.002[a]

[a] Statistically significantly different mean values ($P \leq 0.050$).

from 65 to 93 years old. The majority of the participants were female and reported no smoking or alcohol consumption. More than half of the participants had graduated from high school or higher level of education.

The mean score of oral healthcare-related knowledge significantly increased after the intervention, with a significant level <0.001 (see Table 5). Prior to the educational program, the two most common misunderstandings among the participants were related to the proper usage and selection of toothpaste (K11) and an interdental brush (K6), with 25% and 29.17% correct answers, respectively. On the other hand, most of the participants demonstrated a good understanding of the proper tongue cleaning (K12) and toothbrush usage (K3 and K4). The correct answers were 95.83%, 91.67%, and 91.67%, respectively (Fig. 4a). After the education program, there was no participant who selected incorrect answers regarding the proper selection and usage of a toothbrush (K1, K3, and K4). The number of correct answers increased for all questions, except for a slight decrease of 4.17% for K12. The questions that showed the highest increase in the number of correct answers were K6, K8, K9, and K13, with an increase of 29.17% (Fig. 4b).

The mean score of oral healthcare-related self-efficacy also significantly improved after the educational program, with a significant level of 0.002 (see Table 5). For negative direction questions (S1—S3), the scores were reversed, a "strongly agree" score indicated the highest self-efficacy. Before the educational program, the lowest percentage of "agree and strongly agree" scores were related to the suitable selection of toothpaste and interdental brush, which was 33.33% for both of S2 and S3 (Fig. 5a). However, the percentage of "agree and strongly agree" scores rose for every question after the education program. Almost all questions had more than 20% increase in the scores. The highest percentage of "agree and strongly agree" score (91.67%) was related to the self-efficacy of the interdental brush usage, S5 (Fig. 5b).

The mean value of C-SUS score was 55.11 ± 15.21. According to CGS, the score was rated as D. It did not reach the average level of the usability test, which requires a score of 70 and is rated as C.[28]

Discussion

MAR has been integrated into many health education programs. Most of them were developed for college students or children to experience a novel learning approach that might mitigate the limitation of the traditional learning methods. To our knowledge, our study was the first study to develop MAR-integrated oral education program for

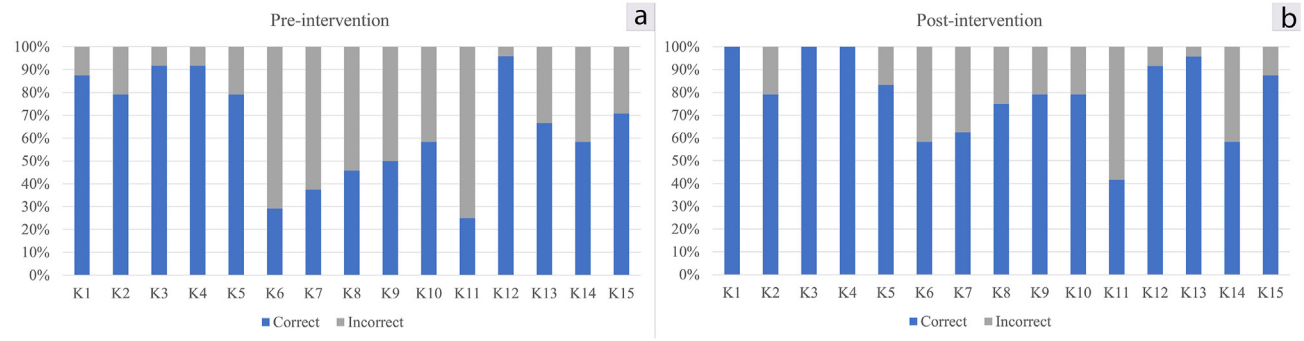

Figure 4 The results from oral healthcare-related knowledge questionnaire. K refers to the questions from Table 2. (a) The pre-intervention results. (b) The post-intervention results.

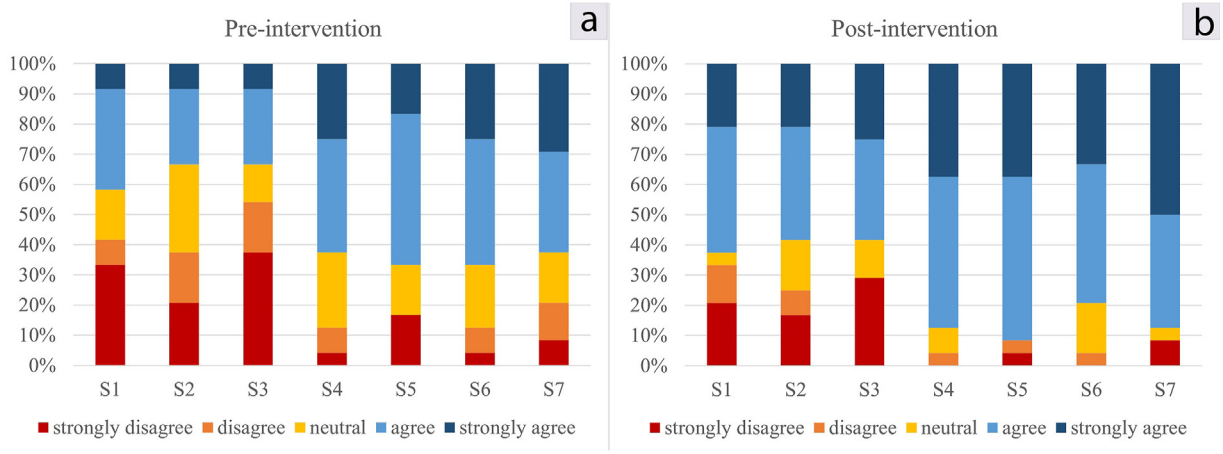

Figure 5 The results from oral healthcare-related self-efficacy questionnaire. S refers to the questions from Table 3. (a) The pre-intervention results. (b) The post-intervention results.

community dwelling older adults. We believe that new generations of older people could also adopt the benefits of the MAR-integrated educational program to improve their knowledge and self-efficacy. The findings of our pilot study showed that MAR-integrated oral health education significantly enhanced participants' oral healthcare-related knowledge and self-efficacy. This aligns with a study conducted by Lee in 2023, which also utilized a mobile application for oral health.[9] Although oral healthcare-related self-efficacy was correlated with oral health status in certain studies,[29] this factor alone may not directly indicate oral health outcomes. Accordingly, it is crucial to assess clinical outcomes in the future study.

In the present time, there is plenty of oral healthcare products available. However, our findings indicated that the majority of participants lacked the knowledge to select appropriate oral healthcare products, especially toothpaste and interdental brushes. Our educational program effectively mitigated this issue by nearly doubling the proportion of participants who correctly answered the related questions. In a similar manner, self-efficacy scores related to the selection of proper toothpaste and interdental brushes were initially low but increased by 25% following the educational program. Accordingly, our program did not only improve oral healthcare-related knowledge and self-efficacy of the older adults in general, but also mitigated the crucial pain points as mentioned above.

The usability score obtained from the C-SUS in our study was lower than the average, which may affect the learning outcomes. However, significant improvement of the learning outcomes was still observed after the intervention. We hypothesize that if the system has a higher usability score, the learning outcomes may have more statistically significant improvement. The lower usability score may be attributed to a reported difficulty experienced of older people when adapting to new technologies.[30,31] Regularly, the assistance of family members is required. Accordingly, the usability of the MAR system needed to be improved. Since these findings were based on the short-term outcome, the participants had no time to adapt with our provided system. We also expected that familiarity with the system, after long-time used, could increase the SUS score.

Beside the benefits of MAR-integrated oral health educational program from our reported results, MAR system can provide the benefits from ubiquitous learning concept that the participants are able to review what they learnt wherever and whenever they would like to.[13] However, our short-term pilot study cannot assess those benefits. Accordingly, some limitations of our pilot study should be considered. Firstly, the outcome assessments were limited

to short-term evaluation and focused solely on knowledge and self-efficacy. In addition, the absence of a control group hindered the validation of the intervention's effectiveness. For future study, it is recommended to conduct long-term evaluations and incorporate other outcome measures, such as clinical outcomes. Comparative groups, including a control group or a group of the traditional educational approach, would be advantageous to draw a conclusion about effectiveness of the MAR-integrated oral educational program.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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