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Effectiveness of a school-based educational intervention on oral health knowledge, attitudes, practices, and self-efficacy among female secondary school students: a randomized controlled trial

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Abstract

Introduction Oral health is crucial during adolescence, yet many young individuals engage in suboptimal oral hygiene behaviors, contributing to oral health issues. While genetics may have some influence, lifestyle factors such as diet, preventive care, and oral hygiene practices play a more critical role in the development of dental caries. The World Health Organization recognizes oral health as a lifelong cornerstone of overall well-being. This study aimed to evaluate the effectiveness of a school-based educational intervention for improving oral health knowledge, attitudes, practices, and self-efficacy among female secondary school students in Kashan, Iran.

Methods This randomized controlled trial was conducted in 2023 with 80 female students aged 12 years from two public schools at Kashan. The participants were selected via cluster sampling and randomly assigned to either the intervention group ($n=40$) or the control group ($n=40$). Data were collected at baseline, one month postintervention, and three months postintervention via a standardized questionnaire administered to both groups. The intervention consisted of four weekly 90-minute educational sessions led by a dentist and a health education specialist, with a focus on oral health knowledge, attitudes, practices, and self-efficacy. Additionally, the intervention group received a digital educational booklet, while parents were provided with a checklist to monitor their children's tooth brushing and flossing behaviors. The control group did not receive any educational intervention or a checklist for tracking oral hygiene behaviors during the study period. Dental plaque levels were assessed via plaque-disclosing tablets (PDTs) at baseline and three months postintervention. Data analysis was performed via SPSS version 24, which employs the chi-square test, Wilcoxon test, Mann–Whitney test, and Friedman test.

Results There was a significant difference between the intervention and control groups in all the measured variables after the intervention ($p<0.001$). Postintervention, the intervention group demonstrated significant increases in

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mean scores for oral health knowledge (from 5.4 to 9.3), attitudes (from 55.6 to 62.1), self-efficacy (from 53.5 to 62.7), and practices (from 28.0 to 33.4) ($p < 0.05$). No significant changes were observed in the control group ($p > 0.05$). There was a significant difference between the intervention and control groups in all the measured variables after the intervention ($p < 0.001$). The average score of dental plaque was significantly different between the two groups ($p < 0.001$). The Wilcoxon test revealed that after the intervention, the test group had improved indicators, and the control group had increased dental plaque scores.

Conclusion The educational intervention effectively enhanced oral health knowledge, attitudes, self-efficacy, and practices among female students. The incorporation of such interventions into school health programs may promote long-term improvements in oral health behaviors among adolescents.

Trial registration Clinical Trial Registry (IRCT code: IRCT20180827040889N1), registered on 27/01/2024.

Keywords Oral health, Health education, Students, Dental plaque, Self-efficacy

Background

The World Health Organization (WHO) identifies dental caries as one of the most significant global health issues, affecting 60–90% of school-aged children worldwide [1, 2]. Iranian children, particularly those aged 12–14, are highly susceptible to oral diseases. The prevalence of dental caries among 12-year-olds in Iran is approximately 60%, with an average decayed, missing, and filled teeth (DMFT) score of 1.84, with girls having higher scores than boys do [3, 4]. A 2014 national screening survey revealed that first-year female secondary school students in regions such as Kashan presented the highest dental caries rates, at 62% [5]. The prevalence of gingivitis among Iranian children also varies, from 37.8% among 6-year-olds in Rayen to 97–98.5% among 6–9-year-olds in Qazvin [6, 7]. While fluoride toothpaste use has become widespread, oral hygiene knowledge and practices among Iranian schoolchildren remain unsatisfactory [8, 9] These findings emphasize the significant burden of oral health issues among students and the critical need for preventive and educational interventions.

Systematic reviews emphasize the importance of theory-based education, particularly Bandura's self-efficacy theory, in improving oral health outcomes among students. This framework focuses on individuals' confidence in their ability to execute behaviors required to achieve desired outcomes. Bandura identified four key components that influence self-efficacy: mastery experiences, observational learning, verbal encouragement, and physical/emotional states [10, 11]. For example, self-efficacy in oral health is strongly linked to improved behaviors such as consistent tooth brushing and flossing, which contribute to lower plaque levels and better periodontal health outcomes [12]. In this study, Bandura's model is operationalized to address gaps in students' oral health knowledge, skills, and behaviors by promoting repetitive practice, peer modeling, and emotional support to increase confidence and self-care abilities.

Several studies highlight the effectiveness of school-based educational interventions in improving oral health among students. A study in India on 10–12-year-olds demonstrated significant reductions in plaque, gingivitis, and caries rates following interventions involving practical demonstrations and educational sessions [13, 14]. Similarly, a Serbian study with 112 students aged 12 years reported that implementing four educational sessions over six months resulted in measurable improvements in oral health behaviors and reduced plaque levels [14]. Moreover, interventions leveraging verbal encouragement and mastery experiences have been shown to engage students effectively, as demonstrated by Laiho et al.'s research on motivation strategies in health education. These findings underscore the role of structured school-based programs in improving oral health outcomes through education, skill-building, and behavioral modeling. This study aims to evaluate the effectiveness of a school-based educational intervention in enhancing oral health knowledge, attitudes, practices, and self-efficacy among female secondary school students at Kashan. Grounded in Bandura's self-efficacy theory and supported by behavioral change frameworks such as the knowledge, attitude, and practice (KAP) model [15–17], the intervention hypothesizes that structured educational programs can significantly improve oral health outcomes. The study employs evidence-based strategies, including peer modeling, skill mastery, and verbal reinforcement, to assess the efficacy of theory-driven approaches in addressing oral health challenges among Iranian students.

Primary hypothesis Class-based educational intervention ("Labkhande Sepid"), complemented by a digital booklet, significantly improves the following variables in the experimental group compared with those in the control group.

1. **Oral health knowledge**: Students in the experimental group demonstrated significantly greater levels of oral health knowledge than those in the control group did.

2. **Attitudes toward oral health**: Compared with the control group, the educational intervention, supported by the digital booklet, led to more positive attitudes toward oral health among students in the experimental group.
3. **Self-efficacy in maintaining oral health**: Students in the experimental group will exhibit greater self-efficacy in maintaining oral health behaviors than their counterparts in the control group.
4. **Oral health practices**: The intervention resulted in improved oral health practices among students in the experimental group compared with those in the control group.

Secondary Hypotheses:

a. Digital educational intervention significantly reduced dental plaque levels in the experimental group compared with those in the control group.
b. The improvements in oral health outcomes (knowledge, attitudes, self-efficacy, and practices) in the experimental group were sustained over time (4 weeks and 12 weeks postintervention).

Null hypothesis There was no significant difference between the experimental group and the control group in terms of oral health knowledge, attitudes, self-efficacy, practices, or plaque levels before and after the digital educational intervention.

Method

Study design, participants, and randomization

This study was a parallel-group randomized controlled trial (RCT). This study adheres to the Consolidated Standards of Reporting Trials (CONSORT) guidelines for the reporting of clinical trials. A completed CONSORT checklist is provided as an additional file to ensure transparency and reproducibility of the methodology.

The study was conducted with 80 female secondary school students aged 12 years from Kashan city. The decision to focus exclusively on female students was informed by findings from a national study conducted in collaboration with the World Health Organization and Iran's Ministry of Health, which revealed that the decayed, missing, and filled teeth (DMFT) index in Iran was 67.1%, with girls exhibiting a higher index than boys [18]. This disparity highlights a greater need for targeted interventions in oral health among female adolescents, making them a priority population for this educational intervention.

Kashan city has 37 female secondary schools, which are geographically distributed across five regions: north (8 schools), south (7 schools), east (5 schools), west (9 schools), and central (8 schools). The city exhibits sociocultural homogeneity across these regions, as it is relatively small in size. However, the organizational restrictions and regulations governing extracurricular interventions in Iranian school settings posed challenges to obtaining collaboration from school staff for this study. Consequently, the lead researcher (AMT) was limited to selecting schools located only in the northern and eastern regions. From the 18 eligible schools in these two regions, two schools were randomly selected via a computer-generated random number list. One school in the northern region, consisting of two seventh-grade classes with a total of 60 students, was designated the experimental group. The second school, located in the eastern region and comprising three seventh-grade classes with a total of 91 students, was designated the control group.

Randomization was conducted to ensure fair and unbiased participant selection at each stage. First, schools within the northern and eastern regions were assigned numbers, and two schools were randomly selected via simple random sampling. Classes were selected on the basis of their similar student population sizes and schedules to ensure comparability. Next, class rosters from the selected schools were used as the sampling frame. In the northern school (experimental group), 40 students were randomly chosen from the total of 60 students via a computer-generated random number list, with 20 students selected from each of the two classes. Similarly, in the eastern school (control group), 40 students were randomly selected from the 91 total students, distributed as follows: 13 students from Class 1, 13 from Class 2, and 14 from Class 3.

A total of 85 students from these two schools were initially assessed for eligibility: 40 from the northern school and 45 from the eastern school. After accounting for 5 students who declined to participate, the final sample consisted of 80 participants, with 40 students from each school.

The randomization process was conducted separately for each school to ensure transparency and reduce bias. To confirm randomness, the sampling process was repeated independently by a second researcher. To prevent cross-contamination, the experimental and control groups were assigned to separate schools located in different regions of Kashan city. Furthermore, the control group was not informed about the intervention being delivered to the experimental group, and vice versa, minimizing the risk of contamination or performance bias.

Inclusion and exclusion criteria

The study population included female school students who met the following inclusion criteria: (1) were seventh-grade students at Kashan, (2) owned a smartphone and possessed the ability to use it, (3) had no prior exposure to oral health training, and (4) provided informed consent to participate. The exclusion criteria were as

follows: (1) withdrawal from school, (2) relocation outside of Kashan, (3) missing more than one training session, and (4) having a physical condition that prevented brushing or flossing teeth.

Sample size calculation

The sample size was determined to be 35 participants per group, on the basis of a confidence level of 95% and a power of 80%, with an estimated 15% attrition rate, resulting in 40 participants per group [12].

Plaque index measurement

Dental plaque was assessed via a standardized plaque index method by a single dentist who was blinded to the group assignments. Measurements were conducted at baseline and three months postintervention in a well-lit room at 8 AM over two consecutive days to ensure consistency. Before the assessment, the students brushed their teeth and chewed a plaque-disclosing tablet, which stained the residual plaque pink (Fig. 1). Plaque levels were scored on the buccal, mesial (using visual inspection and dental probes for precise scoring), distal (inspected under direct light with mirrors for improved visibility), and lingual surfaces via the following scale:

- **0**: No visible plaque.
- **1**: Thin plaque layer at the gingival margin.
- **2**: Moderate plaque accumulation in the gingival pocket.
- **3**: Heavy plaque accumulation in the gingival pocket and along the gingival margin.

The individual plaque index was calculated as the average score across all tooth surfaces and categorized as follows:

- **0–1**: Minimal plaque.
- **1.1–2**: Moderate plaque.
- **2.1–3**: High plaque levels.

To ensure reliability and standardization, the examiner underwent one week of training and calibration under the supervision of an experienced professor at the Faculty of Dentistry, Kashan University of Medical Sciences. Calibration involved repeated plaque assessments on a sample of 20 students, achieving a weighted kappa value of 0.92, indicating excellent intrarater reliability [19]. This rigorous process ensured the accuracy and consistency of the plaque index measurements throughout the study [20].

Data collection instruments

Data collection occurred at three time points: baseline (pretest) from September 23 to October 1, 2023; four weeks postintervention; and twelve weeks postintervention, covering the period from October 2 to May 14, 2024. The questionnaire, originally developed in Persian by Hashemi et al. [12] to assess oral health knowledge, attitudes, practices, and self-efficacy, has already been used and validated in Persian-speaking populations. The modifications ensured cultural and locational relevance for the target population. The key subscales included the following:

- **Knowledge (12 items)**: Each correct response was given a score of 1 point (range: 0–12). Higher scores indicate greater knowledge.
- **Attitude (13 items)**: *Each item was rated on a 5-point Likert scale ranging from "strongly disagree" (1 point) to "strongly agree" (5 points), resulting in a total score range of 13–65. Higher scores indicate more positive attitudes toward oral health. All the items were positively worded, so no reverse scoring was needed.*
- **Self-Efficacy (14 items)**: Confidence in brushing and flossing was rated on a 5-point scale (1 = "not at all confident" to 5 = "completely confident"; range: 14–70). Higher scores reflected greater confidence in oral health behaviors.
- **Practice (8 items)**: Rated on a scale from "always" (5 points) to "never" (1 point) (range: 8–40). Higher scores indicate better adherence to recommended oral health practices.

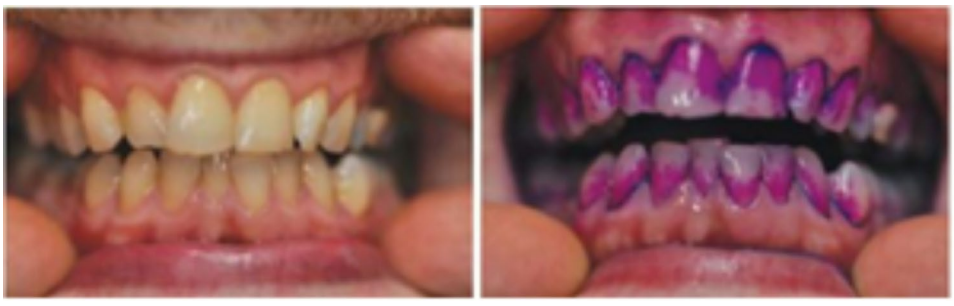

Fig. 1 Plaque stained with plaque revealing agent in students' mouths

Validation and reliability

To ensure the validity and reliability of the modified questionnaire:

- **Content validity**: The questionnaire was reviewed by an expert panel (dentists, health educators, and social scientists). The content validity index (CVI) and content validity ratio (CVR) were calculated, with CVI > 0.62 and CVR > 0.79 indicating strong content validity.
- **Reliability Testing**: A pilot study was conducted with a sample similar to the study population, yielding a Cronbach's alpha > 0.7 for all the subscales, confirming internal consistency.
- **Translation Process**: The questionnaire was administered in Persian, the local language. It was translated from English to Persian via forward and backward translation by two independent bilingual experts. Discrepancies were resolved through discussion to ensure linguistic and conceptual equivalence.

An English version of the questionnaire is provided as supplementary material for transparency.

Intervention program

The experimental group received an oral health educational intervention according to Bandura's self-efficacy theory [15] and three constructs of knowledge, attitudes, and practices driven by the KAP model as the main health change behavior farmwork [10], which was delivered through four weekly sessions under the program name "Labkhande Sepid" (Shiny Smile). Each 90-minute session combined theoretical and practical training on self-care principles—knowledge, attitudes, self-efficacy, and practices—using diverse methods, including lectures, Q&A sessions, group discussions, video presentations, PowerPoint slides, and a digital booklet. The intervention materials were pilot tested with 10 participants from the target population, and their feedback was used to refine the materials for clarity, engagement, and cultural appropriateness. The sessions were conducted by the lead researcher and a trained health educator who had undergone specialized training in oral health education. Group discussions, facilitated by the same educators, ensured consistent delivery. For example, during discussions, students brainstormed strategies to remind themselves to practice oral hygiene behaviors. At the conclusion of these discussions, repetitive suggestions were removed, leaving actionable ideas such as "Let's ask Mom and Dad to remind us" or "Put a picture of a toothbrush on the wall of the room." The group size was kept small (10–15 students per discussion) to encourage active participation and meaningful interaction. The training environment varied: some sessions were held in classrooms, whereas others took place in the school auditorium, which was equipped with audio-visual facilities to support lectures, PowerPoint presentations, and video demonstrations. To standardize education delivery across subgroups, a structured lesson plan was developed, ensuring that all groups received identical content, including predefined discussion topics, consistent educational slides, and synchronized use of videos. The digital booklet, developed following an initial needs assessment involving 290 students, provided comprehensive information on dental hygiene, signs of tooth decay, proper brushing techniques, and the importance of regular dental visits. The content was validated through a Delphi process with input from a panel of health educators, dentists, and students to ensure accuracy, clarity, and engagement. Feedback from multiple rounds was incorporated to achieve consensus. The booklet was accessible via a digital link: https://anyflip.com/swabc/nuqo/. After each session, the digital booklet was shared with the students via a virtual group to reinforce the session's content. Students were instructed to review specific sections before the next session. At the beginning of each subsequent session, comprehension was assessed through questions based on the booklet's content. Students who answered correctly were encouraged and rewarded.

Educational program design and implementation

The educational program was designed on the basis of pretest results, which revealed that students demonstrated relatively higher baseline scores in the attitude construct than in the other constructs, such as knowledge, behavior, and self-efficacy. This finding guided the research team to allocate fewer educational resources to the attitude construct and prioritize constructs where the students' baseline scores were lower. For example, the focus on brushing and flossing behaviors in the session on attitudes was deemed sufficient to reinforce already favorable beliefs while addressing misconceptions. The decision to structure the program in this way aligns with prior studies emphasizing targeted educational strategies for efficiently enhancing oral health outcomes.

To ensure continuity and monitor students' engagement with homework activities, a checklist was developed for parents to document their child's completion of assigned tasks, such as daily brushing and flossing habits or reflections on oral hygiene practices. Parents were instructed to complete the checklist daily and submit it to the researchers at the end of each week. This systematic parental involvement was intended to foster accountability, reinforce the educational messages delivered during the intervention sessions, and provide the research team with reliable data on students' progress (Table 1).

Table 1 Main objectives, sessions, and activities by topic of the oral health program

Topic	Objectives	Headline Of Content (Outline)	Session	Main Activities	Educator
Knowledge	Students understand the importance of oral and dental hygiene. Students can identify ways to prevent tooth decay.	Basic information on oral and dental hygiene, tooth structure, types and roles of teeth, tooth decay process, importance of plaque removal, brushing techniques and frequency, toothbrush selection, and factors affecting dental health.	Session 1	• Slides and video presentations covering oral hygiene basics. • Discussion on the importance of maintaining oral hygiene and its impact on health. • Detailed explanation of tooth decay, plaque, and preventive measures.	Researcher, Health Educator, or Dentist
			Homework	• Activity: "Identifying healthy oral habits."	
Attitude	Students develop accurate beliefs about oral and dental hygiene behaviors.	Information on brushing and flossing behaviors, benefits of regular oral care, and correction of common misconceptions about oral hygiene.	Session 2	• Role-playing exercises and group discussions on brushing and flossing. • Brainstorming on the benefits and myths related to oral hygiene. • Correcting misconceptions through open dialog and interactive activities.	Researcher, Health Educator, or Dentist
			Homework	• Reflection activity: "My reasons for brushing and flossing regularly."	
Behavior	Students practice correct brushing and flossing techniques.	Practical training on brushing and flossing methods, use of mouthwash, diet choices for dental health, and lifestyle factors impacting oral hygiene.	Session 3	• Instructional videos on brushing and flossing techniques. • Hands-on training using a mouth and teeth model. • Group discussion on diet and lifestyle habits that promote oral health.	Researcher, Health Educator, or Dentist
			Homework	• Daily practice log: Students record their brushing and flossing habits.	
Self-Efficacy	Students develop confidence in overcoming barriers to oral hygiene. Students can perform oral health behaviors independently.	Building confidence through skill repetition, strategies for maintaining oral hygiene in challenging situations, and self-monitoring practices.	Session 4	• Group discussion on overcoming barriers (e.g., fatigue, busy schedule) to maintain oral hygiene. • Skill-building through practice and repetition. • Motivational activities using a self-monitoring checklist for tracking oral hygiene behaviors.	Researcher, Health Educator, or Dentist
			Homework	• Activity: "Oral hygiene skills in challenging situations"– role-play different scenarios (e.g., fatigue, illness, social events). • Completion of a self-monitoring checklist.	

To minimize disruption to regular school activities, interventions were scheduled during nonacademic periods (e.g., art class or breaks) with prior coordination from school principals and vice principals. In one instance, the school bell was creatively used to teach the "art" of proper brushing and flossing, engaging students further. Virtual platforms (Eitaa and Bale) were established to facilitate ongoing communication. Supplementary materials, such as videos and reminders about oral hygiene, were shared through these platforms. Parents, particularly mothers, were actively involved via a separate virtual group where they received educational videos, nutritional tips, and checklists for tracking their children's oral hygiene behaviors. This platform also allows parents to ask questions and communicate directly with the research team.

Control group management and contamination minimization

The control group was situated in one school located in different geographical regions of the city, ensuring physical separation from the experimental group. This measure was specifically taken to eliminate any potential contamination or cross-intervention between the groups. The participants in the control group were not informed about the intervention delivered to the experimental group, thereby reducing the likelihood of information sharing or behavioral influence. Furthermore, although the nature of the intervention precluded complete blinding of participants, every effort was made to ensure that neither group interacted socially or academically during the study period. This approach mitigated the risks of contamination and cointervention. The outcome assessors and data analysts were blinded to the group assignments to maintain objectivity in the evaluation of the results. To minimize any clustering effects within

classrooms, students in the experimental group were situated separately from those in the control group, and group assignments were determined before intervention delivery. This approach ensured that the experimental and control groups remained distinct entities without interaction, thereby preserving the methodological integrity of the study.

The control group did not receive any educational intervention during the study period. However, to ensure ethical considerations, they were provided with oral health training materials, including an educational booklet and videos, and participated in an in-person educational session after the intervention phase was completed. All educational content, including the digital booklet, was developed and delivered in Persian, the local language, to ensure cultural and linguistic appropriateness. Additionally, the oral health assessment questionnaire was administered to the control group at three time points: before the intervention, four weeks after the intervention, and 12 weeks postintervention. Furthermore, dental plaque levels were measured in the control group both before the intervention and 12 weeks after the intervention to allow for comparative analysis. The study design adhered to the CONSORT guidelines, ensuring methodological rigor and transparency (Fig. 2).

Data analysis

The data were analyzed via SPSS version 24. Descriptive statistics (frequency, percentage, mean, and standard deviation) were calculated to summarize the participants' demographic characteristics and baseline measures. Inferential statistics were applied as follows:

- **The chi-square test** was used to compare categorical variables between the experimental and control groups.
- **Wilcoxon test**: This test was applied to assess within-group changes over time for nonnormally distributed variables.
- **Friedman test**: Changes across the three time points (baseline, 4 weeks, and 12 weeks) were evaluated within each group.
- **Mann–Whitney U test**: This test was conducted to compare differences between the experimental and control groups for nonnormally distributed variables.

These statistical methods were chosen on the basis of the type of data and the study's objectives to ensure robust and valid comparisons.

Ethical consideration

This study was ethically approved by Tarbiat Modares University's Faculty of Medical Sciences (IR.MODARES.REC.1402.052). The confidentiality of the participants' data was maintained following the Declaration of Helsinki on Ethical Principles in Medical Research. The data were anonymized and stored securely, ensuring that no personal information could be linked to the participants. Only the research team had access to the collected data, and it was not assigned to any external party.

Results

Demographic characteristics

There was no significant difference in age between the experimental and control groups (mean ± SD: 13.05 ± 0.59 and 12.78 ± 0.57 years, respectively; $p = 0.10$). The two groups were also homogeneous in terms of parental education, parental occupation, birth order, and housing status (Table 2).

Effects of the intervention on oral health behaviors

Knowledge

To examine the intervention's effect on the constructs of oral health behaviors, the Friedman test was conducted. The results of the Friedman test indicated a significant difference in the mean scores of knowledge before the intervention, one month after, and three months after the intervention in the experimental group ($p < 0.001$), whereas no significant difference was observed in the control group ($p = 0.51$).

Attitude

Similarly, the Friedman test revealed significant differences in the attitude scores of the experimental group over time ($p < 0.001$), whereas the scores of the control group did not significantly change ($p = 0.92$).

Self-Efficacy

The results also revealed significant differences in self-efficacy scores for the experimental group at different time points ($p < 0.001$), with no notable changes in the control group ($p = 0.11$).

Practice

Finally, the practice scores of the experimental group were significantly different before, one month after, and three months after the intervention ($p < 0.001$), whereas those of the control group were not significantly different ($p = 0.08$). (Table 3).

Comparative analysis between groups

For comparisons between two groups at different time points, the Mann–Whitney U test was used. The results revealed no significant difference between the groups before the intervention across any variable ($p > 0.05$). However, postintervention, a significant difference was observed ($p < 0.001$), with the experimental group achieving higher mean scores than did the control group. This

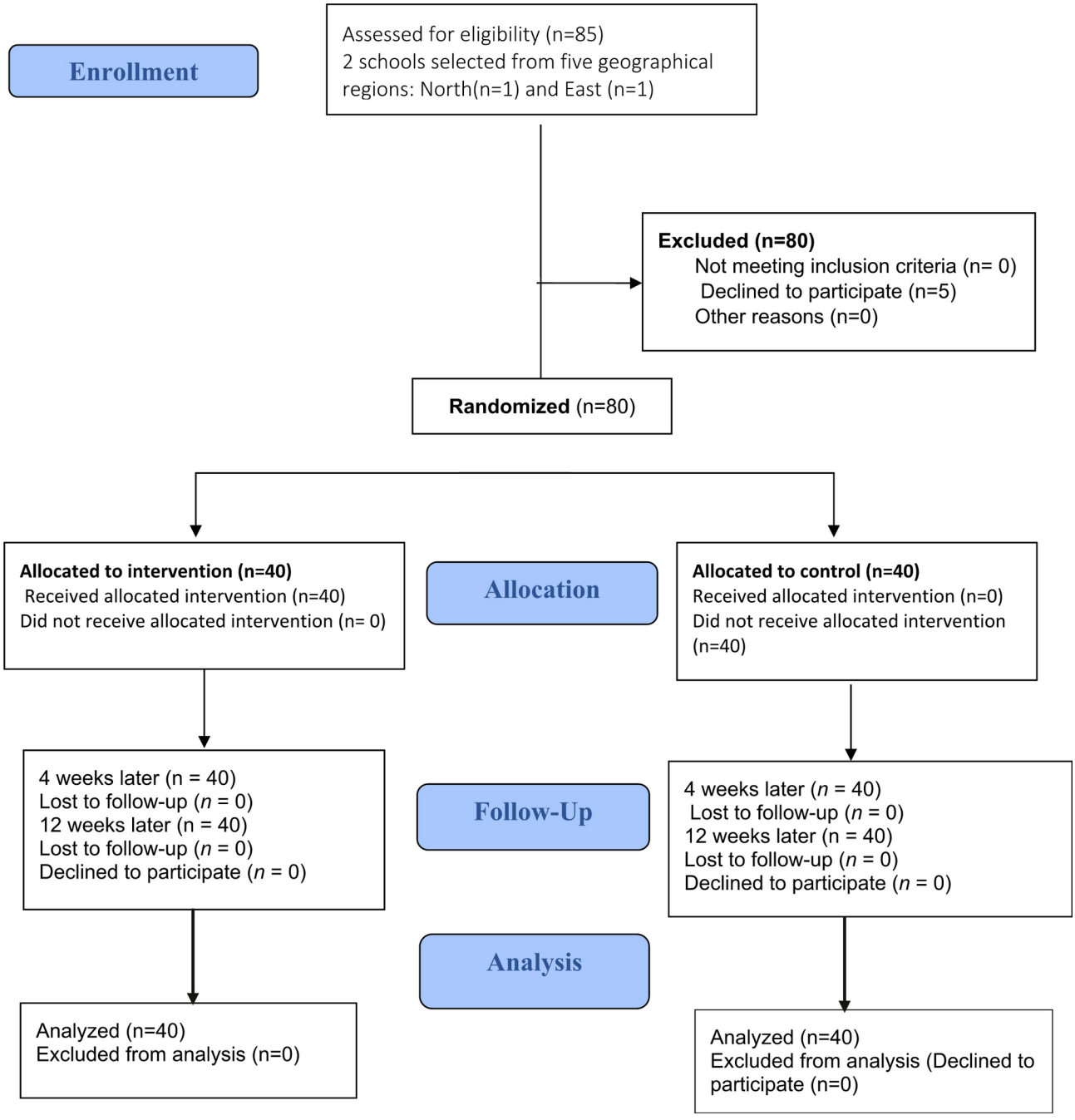

Fig. 2 CONSORT diagram

significant difference persisted at the 12-week follow-up, with the experimental group maintaining higher mean scores ($p < 0.001$) (Table 3).

Plaque levels

Before the intervention, plaque levels were comparable between the experimental and control groups. Three months postintervention, however, the experimental group had a mean plaque index of 0.5 ± 0.5, whereas the control group's mean plaque index was notably greater at 2.3 ± 0.69. The Mann–Whitney U test confirmed a significant difference between the groups ($p < 0.001$), demonstrating the effectiveness of the intervention in reducing plaque. Additionally, the Wilcoxon signed-rank test revealed a significant decrease in plaque scores over time in the experimental group and a significant increase in the control group ($p < 0.001$). (Table 4).

Table 2 Frequency distribution of demographic characteristics of the participants in each group

Variables	Subgroup	Experimental ($n=40$)		Control($n=40$)		p value
		Frequency	Percentage	Frequency	Percentage	
Father's education	Secondary school	11	27.5	8	20	0.103
	Diploma and associate degree	27	67.5	23	57.5	
	Bachelor's degree and above	1	2.5	8	20	
Mother's education	Secondary	10	25	6	15.8	0.44
	Diploma and associate degree	24	60	22	57.9	
	Bachelor's degree and above	6	15	10	26.3	
Father's occupation	worker	10	25	6	15	0.33
	Employee	6	15	10	25	
	Self- employed	24	60	24	60	
Mother's occupation	Housewife	32	80	34	85	0.69
	Employee	8	20	6	15	
Rank of children	First	18	46.2	20	50	0.90
	Second	13	33.3	14	35	
	Third and above	9	20.5	6	15	
Housing status	Own house	34	85	29	74.3	0.49
	Rental house	6	15	10	25.6	
Age		Mean (+ Sd)		Mean (+ Sd)		p value
		13.05 ± 0.59		12.78 ± 0.57		$p=0.10$

Table 3 Mean and standard deviation of the knowledge, attitude, self efficacy and practice

Variables	Groups	Before (Pre-Test)		Post-Test 4 Weeks Later		Post-Test 12 Weeks Later		P Value*
		Mean	(+ Sd)	Mean	(+ Sd)	Mean	(+ Sd)	
Knowledge	Experimental	5.4	1.8	9.3	1.5	9.7	1.3	< 0. 001
	Control	5.5	1.9	5.9	1.6	6	1.8	0.51
	p value**	0.81		< 0. 001		< 0. 001		
Attitude	Experimental	55.6	6.7	62.1	2.5	62.4	3.4	< 0. 001
	Control	55	7.2	53.4	7.7	54.8	5.9	0.92
	p value**	0.44		< 0. 001		< 0. 001		
Self efficacy	Experimental	53.5	11.5	62.7	7.5	66	4.7	< 0. 001
	Control	49.6	11.9	43.7	11.6	51.7	9.7	0.11
	p value**	0.07		< 0. 001		< 0. 001		
Practice	Experimental	28	7	33.4	3.2	35.2	3.2	< 0. 001
	Control	26.5	4.8	23.7	5.4	27.5	5.7	0.08
	p value**	0.11		< 0. 001		< 0. 001		

* Friedman test

Mann–Whitney U test**

Discussion

The results indicated a significant increase in the knowledge scores of the experimental group at 4 and 12 weeks after the educational intervention, whereas no significant change was observed in the control group. Additionally, between-group analysis revealed no difference in knowledge scores prior to the intervention; however, a significant difference emerged one month and three months postintervention, demonstrating the effectiveness of the educational program in enhancing students' knowledge. These findings align with those of Qarli Pour et al. [21], Deepa et al. [22], Sanadia et al. [23], Makundi et al. [24], Asri et al. [25], and Marashi et al. [26], which underscore the importance of adolescents' knowledge as a critical construct in individual behavior change processes. Repeated educational efforts—delivered through both in-person and virtual methods—can significantly increase knowledge levels. By integrating oral health topics into the curriculum, students can gain valuable knowledge about oral hygiene, dental care practices, and the importance of regular dental check-ups. Therefore, the development of standardized national and institutional (school-based) guidelines focused on improving adolescents' oral health knowledge through engaging and innovative educational approaches is recommended.

In the experimental group, the attitude scores increased one month after the intervention but showed little further improvement three months later. This limited

Table 4 Average and standard deviation of dental plaque of students in both groups

Variables	Stage	Experimental	Control	P Value*
		mean (+SD)	mean (+SD)	
Dental Plaque	Before training	2.1 ± 0.89	2.07 ± 0.91	0.70
	Three months after training	0.5 ± 0.5	2.30 ± 0.69	< 0.0001
	Changes after training	1.6 ± 0.39	0.23 ± 0.22	< 0.0001
	p value**	< 0.0001	0.12	

* Mann–Whitney U test

** Wilcoxon test

Whitney U test is the nonparametric alternative test to the independent sample t test. It is a nonparametric test that is used to compare two sample means that come from the same population and used to test whether two sample means are equal or not

The Friedman test is a non-parametric statistical test used for analyzing repeated measures data. It is mainly used when the assumptions of normality and homogeneity of variances are not met, making it a robust alternative to repeated measures ANOVA

The Wilcoxon test (Wilcoxon signed-rank test) tests whether the mean values of two dependent groups (All longitudinal studies use within-subjects, called dependent groups, designs to assess changes within the same individuals over time) differ significantly from each other. Since the Wilcoxon test is a nonparametric test, the data need not be normally distributed. It is counterpart of the t-test for dependent samples

After you have run an ANOVA (more than two groups) and found significant results, then you can run Tukey's HSD to determine which specific groups's means (compared with each other) are different

Bandura introduced key concepts in childrens' education:

Social Learning Theory: Children learn by observing and imitating others

Self-Efficacy: A child's belief in their abilities influences their motivation and achievement

Social Cognitive Theory: Learning occurs through a dynamic interplay of personal, behavioral, and environmental factors

improvement could be attributed to the high pretest attitude scores among the students. Additionally, indirect education provided by school health educators and oral health-related warnings in schools may have positively influenced students' attitudes toward this topic. In contrast, no significant changes in attitudes were observed in the control group. Studies by Schwarzer et al. [27], Hashemi et al. [12], Deepa et al. [22], Asghari et al. [28], and Makundi et al. [24] have also shown an increase in the attitude scores of the intervention groups, which aligns with the findings of the present study. Considering the critical role of positive attitudes in improving oral and dental health, researchers in future studies should emphasize effective techniques to enhance and motivate students to maintain good oral health behaviors, thereby reducing tooth decay and improving oral hygiene.

Self-efficacy, defined as confidence in one's ability to perform health behaviors, plays a crucial role in adopting desired behaviors [29]. This study revealed a significant increase in the mean self-efficacy scores of the experimental group both one month and three months after the intervention, indicating the positive impact of the educational program. The improvement can be attributed to repeated reminders, encouragement, and skill-building activities focused on brushing and flossing. These efforts enhanced students' confidence in their ability to maintain oral hygiene. Conversely, no significant change in self-efficacy was observed in the control group. Similar findings have been reported by Oveisi et al. [30] Xiaojun et al. [31], Jihouni et al. [32], Sanaei Nezhad et al. (14), Ghorbani et al. [33], Alidousti et al. [34], and Ghafoorifard et al. [35], highlighting that high self-efficacy is essential for sustaining proper oral health behaviors. A significant difference was observed in the mean behavior scores of the experimental group before and after the intervention, indicating the effectiveness of the school-based program. No significant change was found in the control group. Between-group comparisons also demonstrated the positive impact of the intervention on the experimental group compared with the control group. The improvement in behaviors one and three months after the intervention can be attributed to parental involvement through virtual channels, which reinforced students' oral hygiene practices. Parents participated by encouraging their children to brush and floss and by completing a checklist to track these behaviors, fostering self-care habits among students. These findings align with the results of Asawa et al. [36], Kazemi et al. [37], Aurlene et al. [38], Malley et al. [21], Arnett et al. [39] and Yasai et al. [40]. By integrating oral health topics into the curriculum, future interventions could further enhance these behaviors, ensuring sustained improvements in oral hygiene and dental care practices. Given the demonstrated effectiveness of education in improving oral hygiene behaviors among students, especially adolescents, diverse educational platforms, including in-person and virtual methods, are recommended.

The results revealed a significant reduction in plaque scores in the experimental group from baseline to three months postintervention, whereas no significant change was observed in the control group. Between-group analysis revealed no difference in plaque scores between the two groups at baseline. However, three months after the intervention, a significant difference emerged, indicating that the educational program effectively improved plaque index scores in the experimental group. These findings

align with the results of studies by Lakshmi et al. [41]. Sharma et al. [42] and Subedi et al. [43] similarly demonstrated the positive impact of educational interventions on reducing plaque scores. This suggests that when oral health education in schools is reinforced through consistent reminders, repetition of content, and encouragement, it can lead to significant and sustained reductions in plaque levels among students. Furthermore, such interventions have the potential to instill lifelong oral hygiene habits, emphasizing the importance of integrating structured and motivational educational strategies into school health programs.

Strengths and limitations of the study

One of the notable strengths of this study is the significant improvement in oral health performance among the students in the intervention group, which was observed three months after the educational intervention. This improvement can be attributed to the consistent repetition of training at appropriate intervals, which effectively promoted students' oral hygiene behaviors. The implementation of a checklist for recording daily tooth brushing and flossing by the students' guardians or by the students themselves not only facilitated regular practice but also reinforced the content of the intervention, leading to better retention of the learned behaviors. Additionally, employing more objective assessment tools, such as the observation of plaque levels in students, provides a clearer picture of changes in oral hygiene behaviors. The inclusion of a control group receiving no intervention ensured a rigorous comparison, allowing the study to isolate the true impact of the intervention by ruling out external influences and providing a valid benchmark for the observed outcomes.

However, this study was conducted exclusively among secondary female school students, which limits the generalizability of the findings to other age groups and demographic populations. To enhance the applicability of these results, it is recommended that similar studies be conducted among students across various age ranges, educational level backgrounds, and ethnic background groups. Another limitation is that data on health behaviors were collected through self-reports from the target group, which may introduce bias. Future research should consider implementing a longer follow-up period to monitor behavioral changes over time, thereby better addressing the research objectives and assessing the sustainability of these changes in the long term. Moreover, it is essential to provide targeted, model-based training for teachers, health educators, and school administrators, along with the active involvement of students' parents—particularly mothers—in the educational process.

Conclusion

The findings of this study demonstrate that the educational intervention significantly enhanced knowledge, attitudes, self-efficacy, and practices related to oral hygiene behaviors among students. This improvement was further reflected in behavioral outcomes, particularly in the increased use of toothbrushes and dental floss, as well as the reduction in plaque scores in the experimental group. These results highlight the effectiveness of utilizing Bandura's self-efficacy theory as a theoretical framework for designing and implementing oral health interventions. Education-based programs have shown considerable success in promoting community education and driving behavioral change. Moreover, the study underscores the critical need for health policymakers to prioritize the development of effective, affordable, accessible, and inclusive educational strategies to improve adolescent oral health. Such efforts are essential for reducing oral health disparities and fostering sustainable improvements in oral health practices among young populations.

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

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Author contributions

AMT wrote the main manuscript draft, and F.Z., A.H., and M.T. supervised the results and analysis. All the authors reviewed the manuscript.

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Data availability

The datasets utilized and/or analyzed in the present study can be obtained from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate

All methods were carried out following relevant guidelines and regulations (Helsinki Declaration of Ethical Principles for Medical Research. Ethical approval was obtained from the Ethics Committee of the faculty of medical sciences at Tarbiat Modares University (IR.MODARES.REC.1402.052). Data collection was carried out with a questionnaire after informed consent was obtained from the students who were eligible and who volunteered to participate in the study, and informed consent was also obtained from their parents.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

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