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Varkey Nadakkavukaran Santhosh[1], Siva Shankkari[1], David Coutinho[1]✉, Anil V Ankola[1], Roopali M Sankeshwari[1], Vinuta Hampiholi[2], Anu Sara Varghese[1], Yuvarani Kandasamy Parimala[1]

EFFECTIVENESS OF A TOOTHBRUSHING INTERVENTION UTILIZING PUZZLE-SOLVING GAME ASSISTED WITH VISUAL AIDS AMONG ADOLESCENTS: A SINGLE-BLIND RANDOMIZED CONTROLLED TRIAL

[1]Department of Public Health Dentistry, KLE Vishwanath Katti Institute of Dental Sciences, KLE Academy of Higher Education and Research (KLE University), Belagavi, India

[2]Department of Periodontology, KLE Vishwanath Katti Institute of Dental Sciences, KLE Academy of Higher Education and Research (KLE University), Belagavi, India

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Address for correspondence:
David Coutinho
Department of Public Health Dentistry, KLE VK Institute of Dental Sciences,
KLE Academy of Higher Education and Research (KLE University), Belagavi, India;
email: coutinho.david8@gmail.com

ABSTRACT

BACKGROUND. Maintaining good oral hygiene through effective toothbrushing is crucial for preventing dental issues in adolescents. Conventional oral health education (OHE) and video demonstration approach are passive means of OHE, that often fail to engage this age group. This study introduced an innovative approach to OHE by combining jigsaw puzzle and visual aids to improve oral health outcomes among adolescents.

OBJECTIVE. To assess the effectiveness of Jigsaw Puzzle-assisted Visual Reinforcement (JPVR) technique on toothbrushing knowledge, practices, and clinical oral health parameters compared to conventional OHE and video demonstration among adolescents.

MATERIAL AND METHODS. This single-blind randomized controlled trial involved 195 adolescents aged 12-15 years randomly allocated to three groups: conventional OHE (control), video demonstration and JPVR. Interventions were administered, and assessments were carried out at baseline, 1 month, and 3 months. Prior to the start of the study, the oral hygiene aids used were standardized. Outcomes were measured using a self-designed, validated closed-ended questionnaire to assess the toothbrushing knowledge and practices. This was followed by clinical examination carried out using gingival and plaque indices by a blinded examiner.

RESULTS. At baseline, groups had comparable knowledge, practices, and clinical parameters. At 3 months, the JPVR group demonstrated significantly higher knowledge, better practices, lower plaque, and reduced gingival scores compared to other groups.

CONCLUSIONS. The JPVR technique improved toothbrushing knowledge, practices, and clinical oral health parameters among adolescents. This approach fostered active learning and knowledge retention and is a cost-effective strategy for promoting positive oral health outcomes among children.

Keywords: *adolescents, game-based learning, oral health education, oral hygiene status, toothbrushing*

INTRODUCTION

Oral health is a fundamental aspect of overall well-being, and its significance cannot be overstated, particularly during adolescence, a critical period of growth and development (1). Poor oral hygiene practices during this stage can lead to various dental and periodontal problems, which may have long-lasting consequences (2). Maintaining good oral hygiene through effective toothbrushing is crucial for preventing dental caries, gingivitis, and other oral health issues. Hence, Oral Health Education (OHE) plays a vital role especially among school children to improve their oral health outcomes.

Conventional OHE methods for toothbrushing, although valuable, often fail to capture the attention and engagement of adolescents, leading to suboptimal retention and application of the toothbrushing knowledge and practices (3,4). OHE through educational video has shown to improve oral health knowledge (5,6). However, both these methods only provide a passive means of OHE. Consequently, there is a pressing need to explore innovative and interactive approaches that can enhance knowledge, motivation, and practical skills of children in maintaining optimal oral hygiene.

One promising strategy involves the incorporation of game-based learning techniques, which have been shown to effectively promote active participation, increase motivation, and facilitate better knowledge retention (4). Puzzle-solving games, in particular, offer a compelling and engaging way to reinforce crucial concepts through hands-on activities and visual aids (7). Previous studies have demonstrated the positive impact of interactive interventions on oral health knowledge and practices among children and adolescents (8,9). However, there is a dearth of research exploring the effectiveness of puzzle-solving games combined with visual aids as an approach to promoting toothbrushing proficiency in this age group.

Jigsaw puzzles can be an engaging and interactive way to impart OHE among adolescents. It provides an interactive and multisensory approach for OHE. By assembling puzzle pieces depicting oral health concepts, adolescents engage in visual pattern recognition and tactile manipulation, stimulating cognitive processing and retention (10). It fosters teamwork, communication, and problem-solving skills. This hands-on, visual-tactile learning experience caters to diverse learning styles, making OHE engaging and effective for adolescents (11). As children work together to assemble the puzzle, they can actively discuss and reinforce their understanding of proper brushing techniques (12). Furthermore, the sense of accomplishment derived from completing a puzzle can motivate adolescents.

Visual aids in the form of stickers can be used to reinforce the OHE acquired through these puzzles. These aids can serve as reminders of key oral health concepts. By combining the interactive nature of jigsaw puzzles with visual aids, OHE can become more retentive, engaging, and effective for adolescents. This study introduces an innovative approach to OHE by integrating jigsaw puzzles and visual aids for adolescents. It seeks to address the gap in existing literature by using this creative OHE approach among school-going adolescents. Thus, the present study aims to assess the effectiveness of Jigsaw Puzzle assisted Visual Reinforcement (JPVR) on toothbrushing knowledge, practices and clinical oral health parameters compared to conventional OHE and video demonstration.

MATERIALS AND METHODS

Study design and study setting. The current study was a three-arm, single-blind randomized controlled trial conducted over three months in 2024 at a public school in Belagavi, Karnataka, India. It followed CONSORT guidelines and was registered with the Clinical Trials Registry—India (CTRI/2024/03/064280).

Sample size calculation. The minimum sample size for the current study was estimated to be 177 adolescents and was calculated using GPower program (G* Power Version 3.1.9.4 statistical software) based on a previous study (13). It was calculated with a power of 0.80 and an alpha error of 0.05. However, to compensate for potential dropouts, an additional 10% was factored in. As a result, the final sample size for the study consisted of 195 adolescents, with 65 individuals randomly assigned to each of the three groups in the study.

Selection criteria. The study included adolescents aged 12 to 15 years who met these criteria: provided assent, had parental/guardian consent, and a plaque score over one. It excluded adolescents who were uncooperative, had systemic conditions, or were on medications affecting gingival health.

Ethical Considerations. The study protocol was approved by the Institutional Research and Ethics Committee (Ref no:148, issued June 13, 2023) and followed ethical standards outlined in the Helsinki Declaration.

Assessment plan

Preparatory phase. A self-designed, closed-ended questionnaire was utilized in the study comprising 15 items in English to assess sociodemographic characteristics, toothbrushing knowledge, and practices. The questionnaire had eight questions assessing knowledge of participants. Correct answers were scored as 1, and incorrect as 0. Participants' cumulative knowledge scores ranged from 0 to 8, calculated by summing their scores for each question.

Likewise, the questionnaire had also seven questions evaluating participants' toothbrushing practices. Correct practices were scored 1, incorrect as 0. Participants' cumulative practice scores ranged from 0 to 7, calculated by summing their scores.

A pilot study was carried out involving 15 adolescents. The primary objectives of this pilot study were to evaluate the reliability of the questionnaire, assess the feasibility of the study protocol, gather participant feedback, and determine the comprehensibility of the questionnaire, video demonstration, jigsaw puzzle, and visual aid. Based on the feedback from participants, adjustments were made to accommodate their preferences, such as displaying the video on a larger screen with loud speakers and allowing more time for solving the jigsaw puzzle. However, the results of the pilot study were not included in the final analysis.

The face validity and content validity ratio of the questionnaire were assessed by a panel of five subject matter experts, resulting in a face validity of 84% and a content validity ratio of 0.86. Furthermore, the questionnaire demonstrated good internal consistency reliability, with a Cronbach's alpha value of 0.88.

To maintain uniformity in data collection, a single trained examiner underwent rigorous training for recording gingival and plaque indices under the supervision of subject matter experts. The intra-examiner reliability was assessed using kappa statistics for the Loe and Silness gingival index and the Silness and Loe plaque index. The Cohen's kappa coefficients were found to be 0.82 and 0.89, for gingival and plaque index, respectively, indicating substantial agreement and reliability in the examiner's measurements.

Standardization of oral hygiene aids and randomization. In order to maintain the consistency of the oral hygiene aids used during the study period and minimize any potential bias, all participants were provided with a standardized soft-bristled toothbrush and fluoridated toothpaste. They were instructed to use the same during the study period and replacements were provided in case of any loss. The study sample comprised of 195 adolescents, recruited through a simple random sampling technique. They were randomly allocated into three groups using a computer-generated table of random numbers. All three groups received conventional OHE on toothbrushing. Group 1, the control group (n = 65) received only the conventional OHE. Whereas Groups 2 and 3 received the video demonstration on toothbrushing and the JPVR technique, respectively, in addition to the conventional OHE. To ensure allocation concealment, the present study employed the SNOSE (Sequentially Numbered, Opaque, Sealed Envelope) technique. The questionnaire to assess toothbrushing knowledge and practices was individually administered to the children prior to their clinical examination, where the examiner recorded

their gingival and plaque scores. The nature of the intervention implemented by the investigator remained blinded from the examiner**.**

Administration of intervention. Following the baseline assessment, the principal investigator held a 20-minute OHE session on effective toothbrushing techniques and practices for all three groups in an auditorium. School teachers were present to facilitate smooth delivery of the session.

JPVR technique: In this group, every adolescent was provided with visual aids in the form of stickers demonstrating the proper toothbrushing techniques. They were instructed to attach these stickers to their diaries to reinforce the knowledge they had gained through conventional OHE. It was also used as an aid to complete the jigsaw puzzle.

Participants were randomly divided into 13 subgroups, each with 5 people, using computer-generated randomization. Each subgroup worked on putting together a 45-piece jigsaw puzzle that showcased proper toothbrushing methods, mirroring the visual aids. They were given a 30-minute time limit to finish the puzzle, and the first group to complete it received a reward. The contents of both the visual aid and the puzzle were validated by subject matter experts.

Video demonstration: Participants in this group were shown a video demonstrating the correct toothbrushing technique on a large screen after receiving the OHE. The video shown for demonstration was taken from YouTube: (https://www.youtube.com/watch?v=O4wDITXrvrc) and was 2 minutes long. The contents of this video were validated by subject matter experts.

Conventional OHE: The control group received only conventional OHE which focused on the correct toothbrushing techniques. The conventional OHE was caried out as a one-way lecture which had demonstration on a model. The content of toothbrushing techniques in all three intervention groups were uniform.

Participants received reinforcement of the interventions at scheduled time intervals during the 1st, 4th, and 8th week. A CONSORT flow diagram illustrating the study design is shown in Figure 1.

Follow-Up. The study had two follow-up assessments, conducted at the first and third month, respectively. During the first- and third-month of follow-up, the same examiner, who remained blinded throughout the study, recorded the gingival and plaque scores for all participants using the same indices employed at baseline. At the 3rd month, an identical questionnaire to the one used at baseline was administered to assess the knowledge and practices of the participants across all groups.

To preserve the integrity of study, participants were intentionally not informed of the exact dates for reinforcement sessions and assessments. At the conclusion of the study, both the video demonstration and JPVR technique were shared with all groups as a moral obligation.

Statistical analysis. The acquired data was entered into Microsoft Excel 2020 and analysed using IBM SPSS® Statistics for Windows, Version 21.0. Continuous variables were presented as mean ± standard deviation, while categorical variables were reported as frequencies. The Shapiro–Wilk test confirmed a non-normal distribution, so non-parametric tests were used: Kruskal-Wallis for unpaired data and Wilcoxon signed rank and Friedman tests for repeated measures. These tests were followed by their respective post hoc tests. Drop-out analysis was also carried out. Statistical significance was set at $p \leq 0.05$

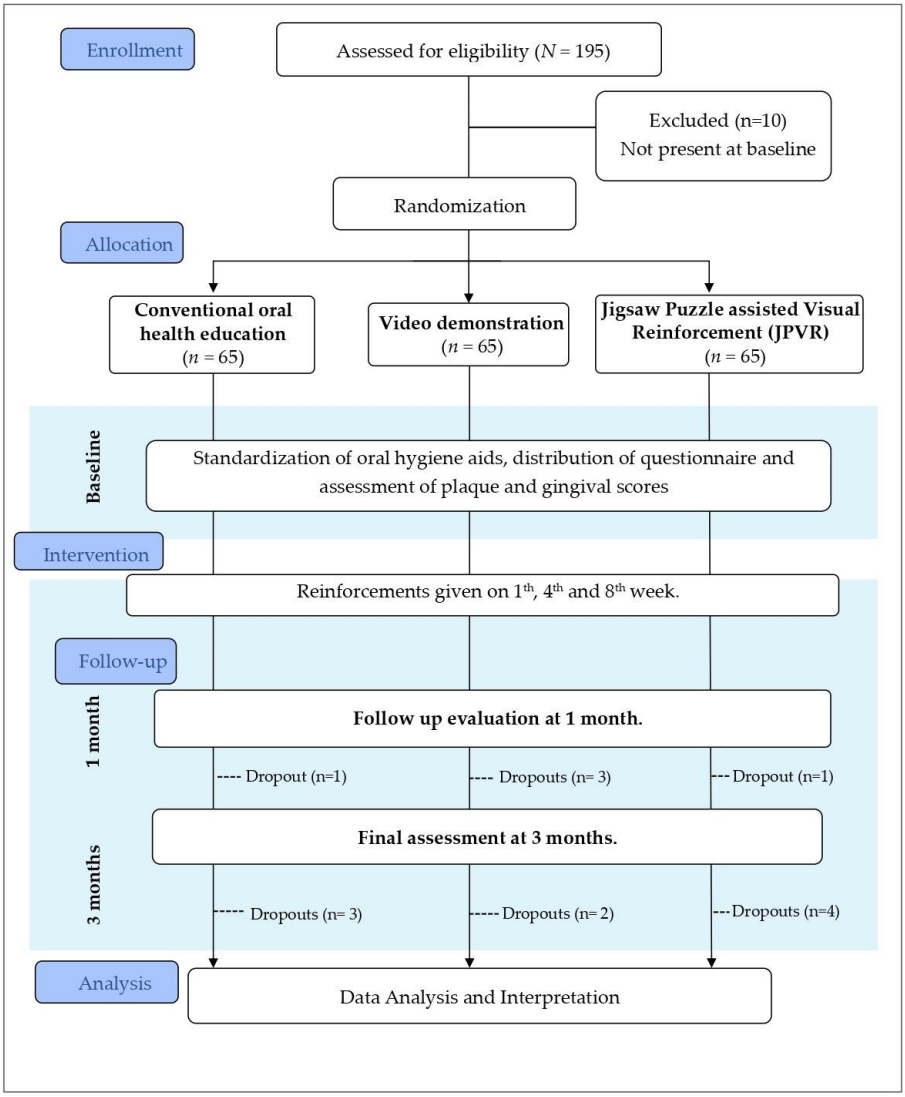

Figure 1. Consolidated Standards of Reporting Trials (CONSORT) diagram

RESULTS

The current study comprised of 195 adolescents, among which 64.1% were females and 35.9% males. The mean age of the participants in conventional OHE group, video demonstration group, and JPVR technique group were 13.29 ± 1.06, 13.14 ± 0.88 and 13.02 ± 1.20 years, respectively. Table 1 summarizes the demographic profile of the participants. Dropout analysis showed that there was no significant difference between dropouts and completers. This indicates that there was no bias from differential attrition. Table 2 presents the comparison of mean knowledge and practice score among three groups at baseline and three months. At baseline all the three groups had similar knowledge (P = 0.626) and practice (P = 0.863). It was observed that there was a significant gain in knowledge and improvement in practice at 3 months compared to baseline in all three groups (P <0.001). However, the knowledge gained and the practices improved was significantly higher in JPVR technique compared to other two groups. This indicates that the JPVR group was more effective in increasing the knowledge and practices scores at the end of 3 months among these school children compared to the other two groups (Table 2).

Figure 2 and 3 presents the mean score of plaque and gingival index at baseline, 1 month and 3 months among three groups. The mean score of plaque (P = 0.583) and gingival index (P = 0.950) at baseline displayed no significant difference among all three groups. At 1st month plaque scores showed statistically significant difference among all three groups (P < 0.001), with JPVR group (1.34 ± 0.28) displaying highest reduction of plaque which was closely followed by video demonstration group (1.36 ± 0.28). In the third month there was an increase in plaque scores compared to first month in all three groups, however the lowest plaque score was observed in JPVR group (1.39 ± 0.20). Pairwise comparison of the three time points showed statistically significant difference among all three groups (P < 0.001). These results highlight the effectiveness of JPVR technique in reducing the plaque among the children.

When gingival scores were considered, there was no statistically significant difference at baseline (P = 0.950), 1 month (P =0.980) and 3 months (P = 0.857) among all three groups. When pairwise comparison of the three time points was considered, there was a statistically significant difference only in JPVR group (P < 0.001) (Table 3). These results indicate that the JPVR group at the end of 3 months was more effective in reducing the gingival index scores compared to baseline, however it did not bring about a significant reduction compared to other three groups.

Table 1. Demographic profile of the study participants

Demographic profile	Conventional OHE (n = 65)	Video demonstration (n = 65)	JPVR (n = 65)	*P*-value
Gender[#] n (%)				
Male	23 (35.4%)	25 (38.5%)	22 (33.8%)	0.856
Female	42 (64.6%)	40 (61.5%)	43 (66.2%)	
Total	65(100.0%)	65(100.0%)	65(100.0%)	
Age## (Mean±SD)	13.29 ± 1.06	13.14 ± 0.88	13.02 ± 1.20	0.328

SD- Standard deviation; Gender is expressed as frequency and percentage (in parentheses); Age is expressed as mean ± SD; Statistical test used: [#]Chi square test and [##]One-way ANOVA;
Level of significance: P ≤ 0.05 is considered statistically significant

Table 2. Comparison of knowledge and practice score among various groups at different time points

Parameters	Groups	Baseline	3 months	*P* -value[#]
Knowledge (Mean ± SD)	Conventional OHE	2.05 ± 1.81 $^{\alpha}$	3.17 ± 2.18 $^{\alpha}$	<0.001*
	Video demonstration	2.22 ± 1.90 $^{\alpha}$	4.32 ± 2.35 $^{\beta}$	<0.001*
	JPVR	2.32 ±1.83 $^{\alpha}$	6.08 ± 1.67 $^{\gamma}$	<0.001*
	P-value[##]	0.626	<0.001*	
Practice (Mean ± SD)	Conventional OHE	2.14 ± 1.76 $^{\alpha}$	3.28 ± 1.99 $^{\alpha}$	<0.001*
	Video demonstration	2.22 ± 1.71 $^{\alpha}$	4.60 ± 1.94 $^{\beta}$	<0.001*
	JPVR	2.30 ± 1.78 $^{\alpha}$	5.46 ± 1.20$^{\gamma}$	<0.001*
	P-value[##]	0.863	<0.001*	

SD- Standard deviation; All values are expressed as mean ± SD
Statistical test used: [##]Kruskal-Wallis test followed by Dunn's post hoc test (Intergroup comparison – vertical P-value) and [#]Wilcoxon signed rank test; Groups with different Greek letters in superscript shows statistically significant difference with conventional OHE group;
Level of significance: P-value ≤ 0.05 is considered statistically significant

Table 3. Comparison of plaque and gingival scores among the three groups at different time points

Parameters	Groups	Baseline	1st month	3rd month	P-value#
Plaque score (Mean ± SD)	Conventional OHE	1.65 ± 0.26 $^{\alpha a}$	1.58 ± 0.22 $^{\alpha a}$	1.60 ± 0.22 $^{\alpha b}$	<0.001*
	Video demonstration	1.69 ± 0.28 $^{\alpha a}$	1.36 ± 0.28 $^{\beta b}$	1.53 ± 0.25 $^{\alpha c}$	<0.001*
	JPVR	1.64 ± 0.25 $^{\alpha a}$	1.34 ± 0.28 $^{\gamma b}$	1.39 ± 0.20 $^{\gamma c}$	<0.001*
	***P*-value##**	0.583	<0.001*	<0.001*	
Gingival score (Mean ± SD)	Conventional OHE	0.29 ± 0.29 $^{\alpha a}$	0.27 ± 0.24 $^{\alpha a}$	0.28 ± 0.25 $^{\alpha a}$	0.715
	Video demonstration	0.31 ± 0.30 $^{\alpha a}$	0.27 ± 0.28 $^{\alpha a}$	0.28 ± 0.29 $^{\alpha a}$	0.763
	JPVR	0.30 ± 0.30 $^{\alpha a}$	0.28 ± 0.30 $^{\alpha a}$	0.27 ± 0.29 $^{\alpha b}$	<0.001*
	***P*-value##**	0.950	0.980	0.857	

SD- Standard deviation; All values are expressed as mean ± SD
Statistical test used:##Kruskal-Wallis test followed by Dunn's post hoc test(Intergroup comparison: vertical P-value) and #Friedman test followed by Bonferroni post hoc test (Intergroup comparison: horizontal P-value); Groups with different Greek letter (α, β, γ) in superscript show statistically significant difference with conventional OHE group and groups with different letters (a, b, c) in superscript shows statistically significant difference with baseline;
Level of significance: P-value ≤ 0.05 is considered statistically significant

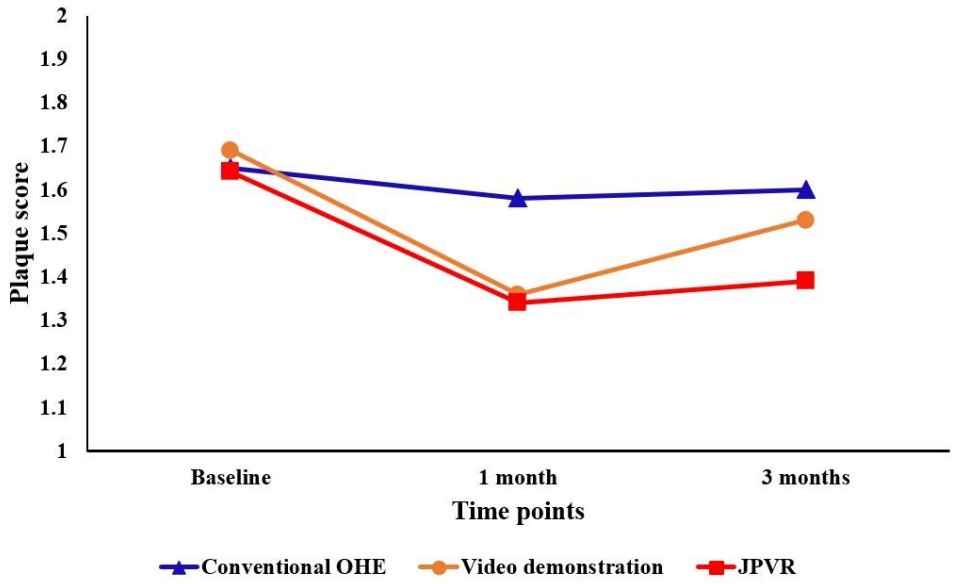

Figure 2. Comparison of mean plaque score among three groups at different time points

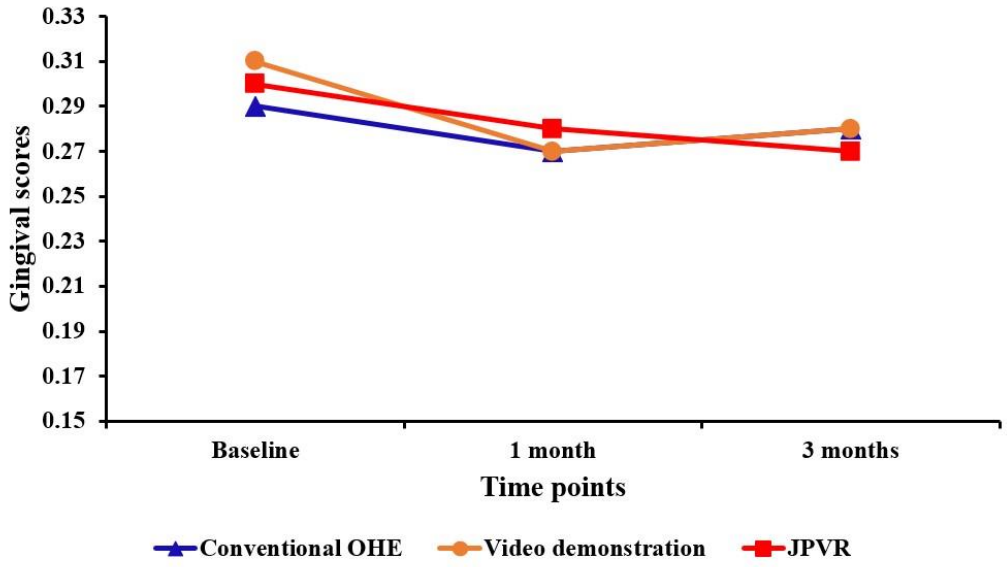

Figure 3. Comparison of mean gingival score among three groups at different time points

DISCUSSION

Game-based OHE offers a more engaging and interactive approach to teaching children about proper toothbrushing practices compared to conventional methods (14). By incorporating elements of play and gamification, it capitalizes on children's natural inclination towards fun and enjoyment, making the learning process more enjoyable and effective (15). Unlike traditional lecture-based approaches, which can often be perceived as dull or overwhelming, game-based education allows children to actively participate and acquire knowledge through interactive scenarios, challenges, and rewards (7). The present study evaluated the effectiveness of JPVR technique in improving toothbrushing knowledge, practices, and clinical oral health outcomes of adolescents, compared to conventional OHE and a video demonstration approach.

The present study demonstrated that all three groups at baseline exhibited comparable levels of toothbrushing knowledge, practices, and clinical parameters, indicating homogeneity among the study participants. This similarity in baseline characteristics across the groups allowed for an unbiased evaluation of the interventions' effects. These findings were similar to that of Kumar et al. (4), and Subedi et al. (16). When the knowledge and practices of all three groups were assessed at three months, there was a stark improvement in all three groups. However, the knowledge retained and practices improved was highest in the JPVR technique group compared to other groups. These findings aligned with other game-based interventions by RS Kumar et al. (4), Liu et al. (17), Mallik et al. (7), and Y Kumar et al. (3).

Active learning methods of OHE such as JPVR, can significantly improve oral health knowledge and practices compared to passive learning methods like lecture-based OHE and video demonstrations. This active JPVR approach encourage learners to actively engage with the material, fostering increased retention and understanding through personalized feedback, practical application of concepts, collaborative learning experiences, and multisensory stimulation (18). By promoting critical thinking, knowledge application in real life scenarios, and peer-to-peer knowledge sharing, JPVR approach create a more immersive and effective learning environment (19). In contrast, passive methods such as conventional OHE and video demonstration may provide a foundation of knowledge but lack the interactive elements essential for deeper comprehension and long-lasting retention of oral health concepts.

The present study demonstrated that in addition to the improved knowledge and practices, the JPVR group also exhibited significant reduction in plaque and gingival indices, indicating the clinical effectiveness of this intervention in improving oral health. The initial reduction in plaque scores at the first-month follow-up across all groups can be attributed to the immediate impact of the educational interventions. However, the sustained reduction in plaque and gingival indices observed in the JPVR group at the third-month follow-up highlights the long-term effectiveness of this approach in promoting better oral hygiene maintenance. These findings aligned with other game based OHE by Kumar et al. (4), Liu et al. (17) and Mallik et al. (7). The interactive nature of the jigsaw puzzle, combined with the visual reinforcement provided by the stickers, may have facilitated active engagement, stimulated cognitive processing, and encouraged hands-on learning, leading to better knowledge retention and application of proper toothbrushing techniques, thereby improving the oral health outcomes.

Using jigsaw puzzles and visual aids as educational tools for OHE can be an effective and cost-efficient approach for promoting good oral health among school children. One key advantage of this approach is their low cost, as jigsaw puzzles and visual aids will likely be a one-time investment. This makes them accessible for schools with limited resources, such as public schools. Additionally, these puzzles can be reused and shared across classrooms, further enhancing their cost-effectiveness. By investing in these educational tools, it can potentially reduce the long-term costs associated with poor oral health among students. Through creative and interactive learning experiences, children can develop a better understanding of the consequences of poor oral hygiene ultimately reducing the burden of oral diseases in the long run.

One of the strengths of the present study include the standardization of oral hygiene aids during the study, eliminating any potential bias arising from differing oral hygiene aids leading

to more reliable results. Additionally, the study assessed both subjective measures (knowledge and practices), and objective measures (clinical parameters). However, the study could have been carried out for a longer follow-up period, as three months may be considered relatively short for assessing long-term sustainability of the interventions' effects. Future studies could incorporate longer follow-up periods to evaluate the durability of the observed improvements. Despite this limitation, the present study provides valuable insights into the potential of innovative, interactive, and multisensory approaches in promoting OHE and improving oral hygiene practices among adolescents.

CONCLUSION

In conclusion, the JPVR technique proved to be an effective and engaging approach for improving toothbrushing knowledge, practices, and clinical parameters among adolescents. By incorporating interactive elements, visual aids, and collaborative problem-solving, the JPVR technique fostered active learning, knowledge retention, and practical skill development. The findings of this study underscore the potential of innovative, multisensory educational strategies in promoting positive oral health outcomes among the adolescent population. Further research exploring the long-term sustainability and applicability of this approach in diverse settings is warranted.

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Address for correspondence:
David Coutinho
Department of Public Health Dentistry, KLE VK Institute of Dental Sciences,
KLE Academy of Higher Education and Research (KLE University), Belagavi, India;
email: coutinho.david8@gmail.com