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ORIGINAL ARTICLE

Impact of Augmented Reality Guided Toothbrushing on Oral Hygiene Parameters Among 6 – 8 Years-old Children: A Pilot Trial

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ABSTRACT

Objective: To determine the effect of Augmented Reality (AR) - based toothbrushing on oral hygiene practices among 6-8yrs old children of Mysuru City. **Material and Methods:** A concurrent parallel examiner-blinded study was conducted on 6-8yrs old children. The participants were divided into two groups: a) the Conventional brushing group and b) the AR-assisted brushing group. Oral hygiene parameters were assessed at the baseline. The conventional group was given a manual toothbrush. The AR-assisted group received a Colgate Magik toothbrush. Both groups were followed up for two weeks. The acceptance of using AR-assisted brushing was recorded via feedback. The pre-post comparison within the group was carried out using a paired t-test. **Results:** An improvement in oral hygiene status with a significant reduction in the AR-assisted brushing group ($p<0.0001$) was observed. The percentage reduction in plaque and gingival bleeding scores was also higher in the AR-assisted brushing group. **Conclusion:** Augmented reality guided toothbrushing is an effective method to teach positive oral hygiene behavior in children.

Keywords: Computer Simulation; Toothbrushing; Oral Hygiene; Technology.

Introduction

Technology has been at the forefront of most evolving aspects of life in an ever-changing world around us. Our routine habits have seen significant improvements through the integration of newer technologies. An area of interest among daily habits that can be further improved is the domestic practices involved in maintaining oral hygiene, especially among children. Studies have shown that the incidence of caries is steadily on the rise in the country [1-4]. This can only be combated by taking appropriate measures, such as educating the masses on the importance of maintaining oral health and committing more to improving access to better oral health tools [5].

Therefore, an intervention with novel technologies at this stage can prove fruitful [6]. Specifically, using Augmented Reality (AR) assisted toothbrushes has shown promising results, considering the oral hygiene status among children [7].

Augmented Reality technology provides an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities. In simpler words, it utilizes a medium between us and the virtual world (the medium here is smartphones) to create an interactive experience. This technology can effectively educate children on tasks and topics that seem uninteresting to them [8]. In toothbrushing, children often need to pay more attention to the task, presuming it to be cumbersome, tedious, and of minor importance, either because they need more education on the topic or because the activity does not appeal to them. With the aid of Augmented Reality assisted toothbrushes, toothbrushing can be turned into an interactive and educative activity for the child. Hence, this study was conducted to determine the effect of augmented reality (AR)assisted toothbrushes on the oral hygiene practices of six-to eight-year-old children.

Material and Methods

Study Design

The efficacy of Augmented Reality assisted tooth brushing was evaluated by an experimental non-randomized concurrent parallel single-blinded study design. The study was conducted in the Department of Pediatric and Preventive Dentistry, JSS Dental College & Hospital, India.

Ethical Clearance

The participants were examined for the selection criteria after obtaining clearance from the Institutional Ethical Committee (IEC) (Protocol no. JSSDCH IEC - 61/2022). The parents and patients voluntarily consenting to be part of the clinical trial were included in the study. Informed consent was obtained from the parents, and permission was obtained from the children before enrolling the participants in the experimental research.

Sampling

The sample size was determined using the formula based on the means. The mean values were obtained from the literature. Based on the formula, the sample size was estimated to be 15 subjects. The following formula was used for determining the sample size:

$$n = \frac{2(Z\alpha+Z\beta)\,(s)^2}{(d)^2}$$

Where, n = sample size;

$Z\alpha$ = constant of 1.96 for a two-tailed study with a confidence level of 95%;

$Z\beta$ = constant of 0.8 at 80% power of the study;

S = Standard deviation;

d = mean difference.

Inclusion and Exclusion Criteria

Children with Frankl's behavior rating of positive and definitely positive, without any medically compromising conditions, were included in the study. Children requiring any form of fixed or removable space maintainers were excluded from the study. Children with multiple carious untreated carious lesions were excluded from the study as it would not have been possible to perform the plaque scoring.

Data Collection

Only 6-8yrs old patients visiting the department were evaluated. The participants were randomly divided into two groups using the sealed envelope method. A single examiner did the screening, allocation, and instructions regarding the brushing technique in both groups.

- Group I: Conventional brushing group;
- Group II: Augmented Reality (AR) assisted brushing group.

After the participants were included in the respective groups, baseline plaque scores (modified Quigley Hein Index) and gingival bleeding scores (Loe and Silness Index) were recorded. A different impartial, calibrated examiner recorded the gingival bleeding scores and the plaque scores. The modified index includes 16, 11, 64, 36, 41, and 84 as the index teeth.

The Gingival Index was assessed as follows: Every tooth's mesial, distal, buccal, and palatal surfaces were examined for gingival bleeding using a Williams periodontal probe inside the pocket to calculate the patients' gingival index. The numbers found for each tooth were added, and averages were computed to calculate each person's gingival index. The gingival index was calculated using Loe & Silness values: 0: Healthy gums; 1: Mild discoloration and oedematous gingiva. No bleeding on probing; 2: Red, oedematous, and shiny gingiva. There is bleeding on probing; and 3: Red, oedematous, and ulcerated gingiva. There is spontaneous bleeding.

The plaque index was assessed according to Turesky et al. [9] modification of Quigley Hein Index: 0: No visible plaque; 1: Separate flecks of plaque at the cervical margin of the tooth; 2: A thin, continuous band of plaque (up to 1 mm wide) at the cervical margin; 3: A band of plaque wider than 1 mm but covering less than one-third of the crown; 4: Plaque covering at least one-third but less than two-thirds of the crown; and 5: Plaque covering two-thirds or more of the crown. The index teeth were chosen because they represent the overall plaque levels in the mouth. Selecting specific teeth made an accurate representation of the amount of plaque in the mouth possible.

Before recording baseline scores, the participants were advised to refrain from performing any oral hygiene practices. After initial screening, the participants were randomly divided into two groups. The participants were educated regarding oral hygiene practices and educated based on the disclosing of the plaque after the application of the disclosing agent. The disclosing agent identified the potential areas in the oral cavity requiring focused brushing. The trained examiner performed a modified Quigley Hein index to measure the extent of plaque on the teeth quantitatively. The participants in Group I, i.e., the Conventional Brushing group, were given a standard oral health care kit, including the age-appropriate manual toothbrush and fluoridated

(1000ppm) toothpaste. The participants were advised to follow Fone's technique of toothbrushing. The participants enrolled in the Augmented Reality (AR) Assisted Brushing program received an Augmented Reality (AR) based toothbrush supported by an interactive mobile application. The application was downloaded to smart mobile phones through the QR code given, along with a sensor-based toothbrush. The participants were assisted in downloading and utilization of the application. The interactive application and the virtual environment would guide the user regarding the appropriate brushing technique.

To maintain impartiality, the supervisor educated the participants independently of the examiner, who performed only the clinical examination and scoring. The participants were advised to follow the recommended brushing techniques for two weeks. The study required a 15-day follow-up. The feedback collected the participants' acceptance and experiences using the Augmented Reality (AR) toothbrushes.

Data Analysis

The data obtained were tabulated and analyzed. First, the data were presented using descriptive statistics (mean, standard deviation, absolute frequency and percentage). Subsequently, the comparison of plaque score and gingival bleeding score between two groups at each time point was performed using a t-test for independent samples. In contrast, the pre-post comparison within the group was carried out using a paired t-test. All the analyses were performed using SPSS Software, version 26.0 (IBM Corp., Armonk, NY, USA), and the statistical significance was tested at a 5% level.

Results

The mean age of the participants in the AR-assisted brushing group was 7.00 ± 0.897, while the mean in the Conventional brushing group was 7.38 ± 0.96 years.

Table 1 and Figure 1 compare the groups' pre-intervention and post-intervention plaque scores. The mean plaque score at the pre-intervention stage differed non-significantly between the two groups (p=0.472); however, post-intervention, the mean plaque scores for the AR-Assisted Brushing group (1.14±0.22) were significantly lower than that of the Conventional brushing group (1.86 ±0.29). This difference in the plaque scores between the groups was significant, with the AR-assisted brushing group showing significantly lower plaque scores (p<0.0001).

Table 1. Intergroup comparison of plaque score between AR-assisted brushing group and conventional brushing group.

Plaque Score	AR Assisted Brushing Group		Conventional Brushing Group		p-value*
	N	Mean ± SD	N	Mean ± SD	
Pre-intervention	16	1.98±0.30	16	2.06±0.32	0.472
Post-intervention	16	1.14±0.22	16	1.86±0.29	<0.0001#

*t-test for independent samples; #Statistically Significant.

Table 2 and Figure 2 compare the groups' pre-intervention and post-intervention gingival bleeding scores. The mean gingival bleeding score at the pre-intervention stage differed non-significantly between the two groups (p=0.521); however, post-intervention, the mean gingival bleeding scores for the AR-Assisted Brushing group (0.83±0.15) were significantly lower (p=0.002).

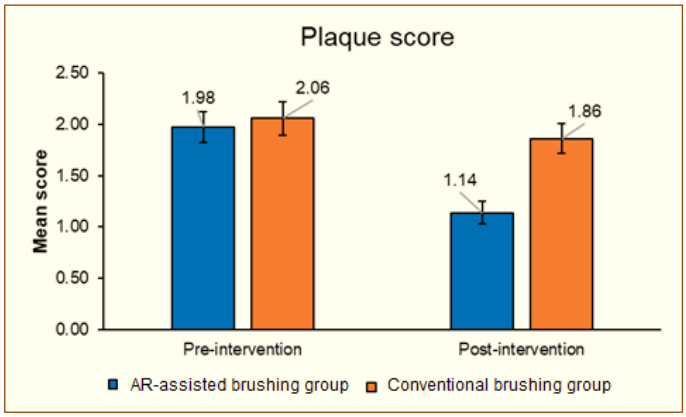

Figure 1. Pre-intervention and post-intervention plaque scores in AR-assisted and conventional brushing groups.

Table 2. Intergroup comparison of gingival bleeding score between AR-assisted and conventional brushing groups.

Gingival Bleeding Score	AR Assisted Brushing Group		Conventional Brushing Group		p-value*
	N	Mean ± SD	N	Mean ± SD	
Pre-intervention	16	1.20 ± 0.12	16	1.23 ± 0.15	0.521
Post-intervention	16	0.83 ± 0.15	16	1.12 ± 0.29	0.002#

*t-test for independent samples; #Statistically Significant.

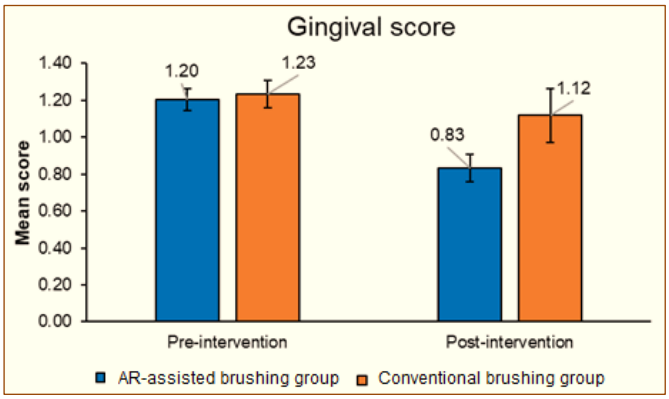

Figure 2. Column chart showing Intergroup Comparison of gingival bleeding score between AR-assisted and Conventional brushing groups.

Table 3 describes the percent reduction in plaque and gingival bleeding scores in both groups from the pre-intervention to the post-intervention stage. Both groups observed reduced plaque scores; however, the percentage reduction was significantly higher in the AR-assisted brushing group with a p-value <0.0001. Similarly, gingival bleeding scores were reduced by 30% in the AR-assisted brushing group compared to 10% in the conventional brushing group.

Table 3. Percentage reduction in different scores from pre-intervention to the post-intervention stage.

Percent Reduction	AR Assisted Brushing Group	Conventional Brushing Group	p-value*
	Mean ± SD	Mean ± SD	
In Plaque Score	42.05±10.45	9.01±4.58	<0.0001#
In Gingival Bleeding Score	30.43±11.44	10.15±4.27	0.001#

*Mann-Whitney U test; #Statistically Significant.

Table 4 describes the responses to the questions about using the AR-assisted brushing method. The responses were obtained only for the AR-assisted brushing group. These responses were recorded at the end of the 15-day follow-up. The table indicates that 68.7% (11 out of 16 participants) of parents and participants agreed that AR-assisted brushing is easy to use. However, 6.3% (1 out of 16 participants) had difficulty using it. 87.5% (14 out of 16 participants) of parents strongly agreed that this newer brushing method motivated the children to perform oral hygiene practices. In the AR-assisted brushing group, 56.2% (9 out of 16 participants) strongly agreed that this method improved the cleaning efficiency. Also, 68.2% (11 out of 16 participants) of parents strongly agreed that the AR app changed the child's brushing technique. All the participants of the AR group (100%) were willing to use the newer method of toothbrushing.

Table 4. Distribution of responses to questions from the AR-assisted brushing group.

Questions	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
	N (%)	N (%)	N (%)	N (%)	N (%)
Did your child find the AR-assisted toothbrush easy to use?	0 (0.0)	1 (6.3)	0 (0.0)	11 (68.7)	4 (25.0)
Do you feel that AR-assisted tooth brushing has motivated the child to brush?	0 (0.0)	0 (0.0)	0 (0.0)	2 (12.5)	14 (87.5)
Do you feel better cleaning efficiency with AR-assisted tooth brushing?	0 (0.0)	0 (0.0)	1 (6.3)	6 (37.5)	9 (56.2)
Did the App bring about change in the way your child brushes?	0 (0.0)	0 (0.0)	0 (0.0)	5 (31.2)	11 (68.2)
Acceptance of AR-assisted tooth brushing?	0 (0.0)	0 (0.0)	0 (0.0)	16 (100.0)	0 (0.0)

Discussion

Toothbrushing is an essential domestic activity that must be done at least twice daily to maintain a healthy oral cavity. Integration of such activities should be done at an early stage as it would eventually become a habit practiced automatically instead of a task to be executed [10].

It has been observed that failure to integrate such behavior in children has resulted in high caries incidence. Most frequently, such individuals are referred to the dental clinic either for endodontic treatment or for complete extraction of the affected tooth/teeth [11]. However, effective health education has proven to be a challenge because of neglect on the educators' part and the children's behavior regarding attention spans, curiosity, and interest in the activity. Capturing a child's attention, especially for a task such as toothbrushing, is very difficult; the activity seems futile and cumbersome for them [12]. This is where the role of AR comes into play. AR sets out to involve and immerse the child across multiple modalities in the task.

The AR-assisted toothbrush aids the child's physical movements and cognition toward toothbrushing through visual and audible means. The child is reinforced every time they perform the instructed movement correctly through the format of a reward system in the video game. Conversely, the toothbrush also detects errors in movement and hence can deduct scored points for incorrectly executed movements. The AR-assisted toothbrush is designed to provide real-time feedback on brushing techniques and motivate children to brush thoroughly [13].

In the present study, children between the ages of 6 and 8 were chosen as it was observed that this age group is ideal for learning essential daily activities [14]. Children of this age start developing their fine motor skills. The child is guided by the AR toothbrush on areas of the mouth where they should brush, areas where extra attention to brushing should be given, the correct way to hold and grip the toothbrush, and the direction of movement of the toothbrush. Daily practice of this routine will eventually make it a habit for the child [15].

The study was conducted on 32 participants divided into two groups. A smaller sample size was considered to prioritize this innovative technology's feasibility and proof of concept. The study lasted two weeks, marked at the beginning and end, by assessing oral hygiene status. During this period, the participants were advised to follow a uniform oral hygiene regime, brushing twice daily. Plaque indices were recorded using the modified Quigley-Hein Index. The disclosing agent was applied on the facial and lingual surfaces of 6 selected teeth (11, 16, 36, 41, 64, 84). The selection of these specific teeth was done based on their function. Each of these teeth takes up significant roles among their types, i.e., incisors and molars. Hence, a considerable accumulation of debris can be observed on these teeth, and eventually, the increase of plaque is most evident on these teeth. The method measures the growth of plaque from the gingival third of the tooth up to the occlusal third. Based on the extent, six scores are given. The use of the Loe and Silness Gingival Index determined gingival health status. The teeth mentioned above were also used for plaque indexing and gingival status determination.

The pre-intervention scoring sessions predictably observed subjects showing high plaque scores and poor to moderate gingival health status. Post this session, the subjects were advised to follow the instructions given and use their administered toothbrush and toothpaste. A period of 14 days between the two scoring sessions was decided as it was determined that it was a sufficient time frame to allow a significant and measurable increase in plaque. A period of two weeks also prevents the given toothbrush from too much wear, which would affect the efficacy of plaque removal [16].

In the post-intervention scoring session, significant differences were observed between the conventional brushing group and the AR group. The conventional brushing group showed a slight improvement in the scores, whereas the AR group showed significant improvement compared to their baseline scores. Plaque scores were significantly lower, and gingival status improved to normalcy. Despite the control group presenting a higher baseline plaque score, the percentage reduction in plaque scoring in both groups supports the fact that the AR-assisted toothbrushing group achieved a more significant decrease in plaque buildup. Further, with the aid of the questionnaire, it was determined that the AR-assisted brushing group showed the initial desired objectives of increased motivation to brush and higher interest in the activity. Similar findings were observed in a study conducted on a larger group of subjects in 2011 to measure plaque scores before and after education using audio-visual or conventional means [17]. Another study in the same year aimed to determine the effect of supervision during toothbrushing in school children [18]. Irrespective of the type of toothbrush used (manual or electric), the groups under supervision fared better on overall oral hygiene scores after the study. Both of these studies, therefore, show that adequate effort toward the cause of better oral health is fruitful. The use of AR in toothbrushing and oral health education has proved to be a helpful tool.

Conclusion

Integrating Augmented reality technology into domestic health care habits, such as toothbrushing, has advantages in improving overall oral hygiene among children. Augmented reality technology has also proven to be an effective educational tool as it can engage and motivate the child for the activity in question. Therefore, the effect of Augmented reality on domestic oral health practices is positive and can be encouraged as an alternative to conventional methods owing to its effectiveness. Nevertheless, it is advisable to conduct further research on the applications of this technology using a larger sample size and extending the duration of follow-up to enhance the generalizability of the findings to the broader population.

Authors' Contributions

SD	https://orcid.org/0000-0001-5169-7811	Conceptualization, Methodology, Validation, Formal Analysis, Writing - Review and Editing and Supervision.

AM	https://orcid.org/0009-0002-7118-7936	Methodology, Writing - Original Draft, Writing - Review and Editing, Project Administration and Funding Acquisition.
SD	https://orcid.org/0000-0001-6196-9374	Validation, Investigation, and Project Administration.

All authors declare that they contributed to a critical review of intellectual content and approval of the final version to be published.

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Conflict of Interest

The authors declare no conflicts of interest.

Data Availability

The data used to support the findings of this study can be made available upon request to the corresponding author.

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