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ORIGINAL PAPER

Developing a Toothbrushing Visual Pedagogy (TBVP) for Preschool Children with Autism Spectrum Disorder

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Abstract
Visual pedagogy and social stories have been widely used to assist children with Autism Spectrum Disorder (ASD) in learning various skills. A toothbrushing visual pedagogy (TBVP) was developed adapting existing toothbrushing social stories for children with ASD. This TBVP consists of 13 toothbrushing steps with scripts describing the toothbrushing technique. To evaluate its feasibility, a review panel was formed to provide feedback on the TBVP and three other published toothbrushing social stories. Effectiveness of the TBVP was further evaluated among 119 preschool children with ASD with significant improvements in toothbrushing skills observed at 3-month and 6-month follow-ups. It is concluded that TBVP is a feasible and an effective educational means that assists children with ASD in learning toothbrushing skills.

Keywords Autism spectrum disorder · Preschool children · Toothbrushing visual pedagogy · Life skills · Oral hygiene

Introduction

Autism spectrum disorder (ASD) is a spectrum of disorders affecting social and communication skills of individuals, with typical onsets in early childhood, which may or may not carry on to adulthood, depending on severity of the condition and responses to therapeutic intervention (Johnson & Myers, 2007; Lord et al. 2000). Impairments in children with ASD not only affect their social and communication skills but also the cognitive functions (Geschwind & Levitt, 2007; Happé & Frith, 2006). Therefore, a majority of children with ASD have difficulties in learning the basic self-caring skills compared with their typically developing peers (Jasmin et al. 2009; Provost et al. 2009; Tomchek & Dunn, 2007).

Oral health is an integral part of the general health of children with ASD. It has been reported that oral health is a strong predictor of the health-related quality of life for children with ASD (Du et al. 2019; Pani et al. 2013). Children with ASD are often more likely to have oral health issues such as dental caries and gingivitis, which have been attributed to their inadequacy in oral hygiene practices (Chan et al. 2014; El Khatib et al. 2014; Lam et al. 2020). Toothbrushing has been shown effective in maintenance of good oral hygiene, thereby reducing caries and periodontal diseases (Attin & Hornecker, 2005; Kang et al. 2008; Seow et al. 2003). However, relative impairments in the social and cognitive functions in children with ASD may hinder them to comply with this simple daily practice, compromising their oral health and increasing the risk of oral diseases.

A series of Social Stories™ and visual aids developed for children with ASD have been proved effective in assisting their learning (Gray & Garand, 1993; Kokina & Kern, 2010). Picture Exchange Communication System (PECS) has been widely used as a communication method, which

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advocates the use of visual guide among children with ASD (Bondy & Frost, 1994; Flippin et al., 2010; Preston & Carter, 2009; Schwartz et al., 1998).

Additionally, the Treatment and Education of Autistic and related Communication Handicapped Children (TEACCH) model also uses visual aids in its training program for children with ASD to enhance holistic learning (Mesibov et al. 2005; Tsang et al. 2007; Virues-Ortega et al. 2013). Researchers and organizations have developed various toothbrushing social stories or visual aids to assist children with ASD in learning the toothbrushing skills (Asma'a et al., 2013; Bäckman & Pilebro, 1999; Orellana et al. 2014; Pilebro & Bäckman, 2005; Stripling et al. 2013). However, most of the toothbrushing social stories are animated drawings, which might not be easily understood by children with ASD with difficulties in communication and cognitive skills, as children with deficiencies in social communication might struggle in motor imitation, language understanding and conventional use of gestures (Landa et al. 2011). Hence, the current study aimed (1) to develop a toothbrushing visual pedagogy (TBVP) to assist parents/caregivers in teaching preschool children with ASD toothbrushing in a step-by-step manner, and (2) to evaluate its feasibility and effectiveness via *qualitative* and *quantitative* evaluations. With regards to the effectiveness of TBVP, the null hypothesis tested was that children with ASD have no improvement in toothbrushing skills after regular use of the TBVP aid.

Materials and Methods

The study was approved by the Institutional Review Board of the University of Hong Kong/ Hospital Authority Hong Kong West Cluster on human research ethics (IRB HKU:12–222), and registered with the HKU Clinical Trial Register (HKCTR-1594).

Materials

To evaluate the content relevance and feasibility of the self-developed TBVP, three published toothbrushing social stories were identified for panel review and comparison. These three social stories are (1) "I can brush my teeth" (Stripling et al. 2013), which is a 12-step social story of toothbrushing as part of a book entitled "Hygiene Bundle"; (2) "Time to brush your teeth", which is a 17-page social story (Handsinautism.org., 1995), and (3) "刷牙社交故事", which is a locally published Chinese toothbrushing social story (Pearson & Smit, 2003).

After searching the existing literature, a 13-step TBVP comprised of a flip-chart storybook and an associated DVD were developed. The flip-chart storybook contained a series of photos of a real boy demonstrating each step of proper toothbrushing, subtitled with simple Chinese and English explanations. The DVD recorded how the boy performed proper toothbrushing, supplemented with verbal explanations, bilingual subtitles and light background music.

Participants and Procedure

Qualitative Panel Review

A panel of 10 members was then formed to review the existing visual pedagogies for toothbrushing as identified from the literature search. We carefully decided the composition of the Review Panel, which included two pediatric dentists, one psychologist consultant, two Special Child Care Centre (SCCC) teachers, two SCCC nurses and three parents of children with ASD. The function of the review panel was to elicit feedback from different personnel who had provided care and treatment for children with ASD. The pediatric dentists were the specialists delivering oral health care for children with ASD and provide quality assurance in toothbrushing. The psychologist offered professional guidance in developing a scientific program of the basic life-skills learning for children with ASD. The SCCC teachers brought a wealth of practical advice on program delivery to children with ASD; while the SCCC nurses and parents shared their first-hand tips of caring and supporting children with ASD, as they provided them with daily primary care.

The panel was requested to review and give feedback on the strengths and weaknesses of the visual pedagogies/ social stories, as well as providing comments for their uses in the local community. To facilitate rating of the visual pedagogies/ social stories, an evaluation form was developed based on the list of criteria (Table 1) recommended by Gray and Garand (1993).

Following the comments from the Review Panel, a revised English and Chinese (traditional Chinese characters) versions of the self-developed TBVP were developed (Fig. 1). The flip-chart storybook and associated DVD were modified and produced, demonstrating and summarizing the 13 toothbrushing steps to the audience. The steps commenced from retrieval and wetting of the toothbrush (step 1–2), followed by application of toothpaste (step 3–4) and positioning toothbrush appropriate to brush teeth at different sites (step 5–9). Finally ended with spitting of toothpaste (step 10), cleaning of toothbrush and face (step 11–12) and storage of toothbrush (step 13) on completion of toothbrushing task (step 13). Steps 5–9 were considered as the key steps for effective toothbrushing.

Table 1 Criteria for evaluating the visual pedagogy/social story

Is there an introduction, body and conclusion to the visual pedagogy/story?
Does the visual pedagogy/story answer the relevant "who" "where" "when" and "what" questions? Sometimes, many of these questions may be answered in a single (often opening) statement
If the story is written for a young student, is it written from a first-person perspective, as like the student is describing the event?
Does the visual pedagogy/story have a positive tone? If negative information is included, is it stated carefully using a third person perspective?
Does the story adhere to either visual pedagogy/ social story Ratio (Basic or Complete)?
Is the story literally accurate? Can it be interpreted literally without altering the intended meaning?
Is alternative vocabulary used in place of terms that may cause the person with ASD to become upset or nervous?
Is the text written with consideration of reading ability and attention span of the person with ASD, using visual supports to enhance the meaning of the story?
If illustrations are used, are they developed and presented with consideration of the ability of the person with ASD?
Has an effort been made to incorporate the student's interests into the format, content, illustrations, or implementation of the story?
Overall, does the visual pedagogy/ story have a patient and reassuring quality?
Does it contain all the necessary steps for practicing toothbrushing?

Quantitative Quasi-Experiment

Study Setting

The evaluation of TBVP was conducted between 2013 and 2014 by contacting the two principal organizations (Spastics Association of Hong Kong and Heep Hong Society) that provided child development and training services to preschool children with special needs in Hong Kong. The services offered by these organizations include self-care training programs relating to toileting, dressing, feeding, grooming, care of personal belongings and basic domestic skills. Their underlying philosophies were that self-care training could aid the development of good personal habits, sense of responsibility and problem-solving skills, which would in turn decrease the burden of parents in taking care of their children. The two organizations were contacted regarding the incorporation of our oral self-care program into the children's daily practice at their centers. Both organizations agreed to participate in this study and invitation letters were sent to parents of preschool children with ASD.

Participant Selection

Preschool children, age ranged from 2 to 6 years old and had a confirmed diagnosis of ASD, were invited to join the study. As the purpose of study was to evaluate the toothbrushing skills improvement, children with ASD were excluded if they (1) only participated in the baseline assessment, but not the subsequent reviews; or (2) could not be evaluated at baseline assessment due to absence or poor cooperation.

Recruitment

Parents of the preschool children at SCCCs were invited to participate in this clinical trial. They were provided with a description of the study and invited to evaluate their child's toothbrushing performance. At baseline, each child was accompanied by their parent(s) to the classrooms of the participated organizations where the evaluation took place.

The children were asked to perform toothbrushing in front of a trained and calibrated examiner (first author), whom received training by carrying out evaluations on 25 preschool children. The intra-examiner reliability reported was good (Kappa > 0.7). The examiner recorded the steps that the children completed on the toothbrushing checklist (Table 2).

To avoid sharing of different toothbrushing behavioral intervention materials among parents and teachers, children were allocated into either interventional or control groups based on the organizations of their SCCCs. Determined by computer-generated random numbers, Spastics Association of Hong Kong and their respective SCCCs receive the TBVP; while the SCCCs of Heep Hong Society were allocated to be the control or comparison group.

Intervention and Assessments

Parents of children in both intervention and control groups received conventional oral health education instructions (OHI) demonstrated on tooth models. Children of both groups were also provided with a standardized toothbrush and two tubes of toothpaste (Colgate® kids fluoride toothpaste, 600 ppm fluoride).

For the intervention group, other than conventional OHI, preschool children and their parents also received the TBVP, a flip-chart story book for home use. Instructions on how to

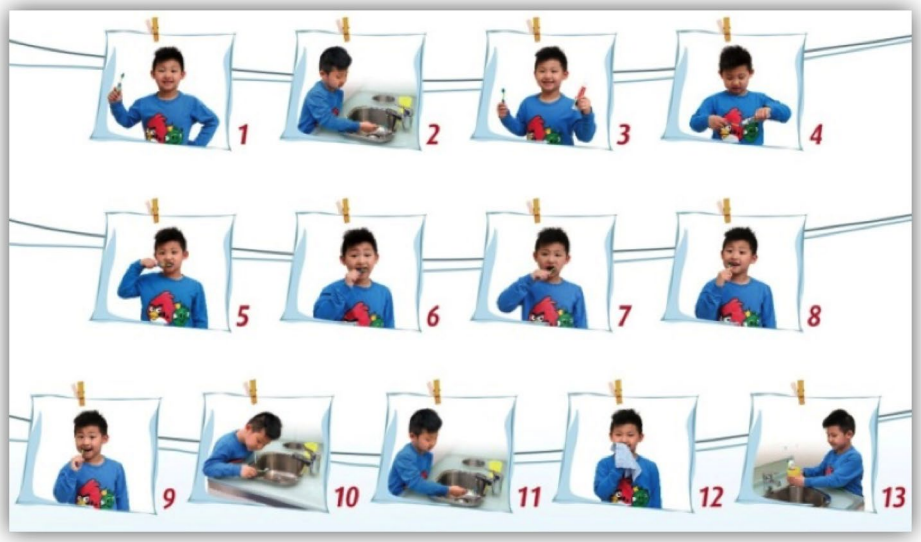

Fig. 1 The in-house developed toothbrushing visual pedagogy (TBVP) for the behavioral intervention

Table 2 Checklist of toothbrushing steps

Steps		By child him/herself	Parent performed the task
General steps	1. Can hold the toothbrush		
	2. Can turn on the tap and wet the toothbrush		
	3. Can hold the toothpaste		
	4. Cansqueeze a pea-size		
Effective steps	5. Can brush his/her front teeth		
	6. Can brush his/her upper posterior teeth on the left side		
	7. Can brush his/her lower posterior teeth on the left side		
	8. Can brush his/her upper posterior teeth on the right side		
General steps	9. Can brush his lower posterior teeth on the right side		
	10. Can spit out the toothpaste		
	11. Can rinse the toothbrush		
	12. Can wipe his/her mouth with a towel		
	13. Can put the toothbrush and toothpaste away		

use the TBVP were delivered in a workshop to the parents and teachers before issuing the flip-chart storybook. Parents and teachers were encouraged to read the TBVP flip chart together with the children during toothbrushing. Parents were also advised to place the flip-chart close to where their children performed toothbrushing, such that their children could follow step-by-step while brushing.

In addition, the associated DVD was distributed to the school teachers of the respective SCCCs, such that they can play the DVD when teaching the toothbrushing skills to the children in class. The DVD was also made available to the parents or caregivers to supplement the flip-chart.

Parents were asked to record their use of the TBVP provided and submit them in the subsequent reviews. A diary was provided for parents and teachers to record the frequency of using the TBVP, and for investigators to evaluate whether they have followed the instructions provided accordingly (Online Appendix 1). Children of both groups were evaluated on their ability to perform the toothbrushing steps at 3-month and 6-month follow-ups with a standardized pro forma (Online Appendix 2).

Data Analysis

SPSS® Statistics version 23.0 (SPSS Inc, Chicago, IL, USA) was utilized for analyzing the data collected by a trained examiner.

The primary outcome was the performance in the task of toothbrushing, expressed in terms of the number of effective toothbrushing steps (step 5–9) performed by the children under verbal guidance, without actual parental assistance. The mean and standard deviations of the number of effective steps of each group at baseline, 3-month and 6-month were assessed by a trained and calibrated examiner and obtained for analysis. Within groups, comparisons of changes over time were assessed with Friedman's Two-Way Analysis of Variance by Ranks; whereas comparisons between intervention and control groups was assessed with Mann–Whitney U test.

The secondary outcome was the rating of the toothbrushing performance by the examiner at subsequent follow-ups, categorized into good, moderate and poor based on the criteria listed in Table 3. Variation in rating of toothbrushing (*'good-moderate-poor'*) over time was determined using *Cochrane Q test* statistics. Comparison in the rating of toothbrushing (*'good-moderate-poor'*) between the treatment and control groups was determined using *Chi-square* statistics.

Results

Content Relevance and Feasibility of the In-house Developed TBVP

Each social story was rated according to 12 criteria as described in Table 1. The ratings varied across the four social stories. The TBVP developed in-house had the highest ratings overall (Table 4).

In addition, open-ended responses from the Review Panel on the strengths, weaknesses and suggestions for improvement of the TBVP were analyzed. These included issues such as the use of photos rather than line drawings, as the latter might not be easily understood by children with ASD with difficulties in communication and cognitive skills. The panel also evaluated the number of toothbrushing steps, the need to include information about exact amount of toothpaste, toothbrushing technique, the sentence structures, the size of photos, and the value of including an associated DVD/music.

Comments from the Review Panel on the strengths, weaknesses and suggestions for improvement were shown in Table 5.

Table 3 Overall rating of toothbrushing performance

Category	Description
Good	a) Can apply tooth paste to brush teeth AND
	b) Can perform brushing of at least three areas (front teeth/ upper posterior teeth left/ upper posterior teeth right/ lower posterior teeth left/ lower posterior teeth right)
Moderate	a) Can apply tooth paste to tooth brush AND
	b) Can perform brushing of two areas (front teeth/ upper posterior teeth left, upper posterior teeth right, lower posterior teeth left, lower posterior teeth right)
	OR
	a) Cannot apply tooth paste to tooth brush BUT
	b) Can perform brushing of at least three areas (front teeth/ upper posterior teeth left/ upper posterior teeth right/ lower posterior teeth left/ lower posterior teeth right)
Poor	Can only perform less than what is required in the criteria of 'Moderate'

Table 4 Number of "Yes" of the criteria questions to evaluate the programs

Evaluation	No. of "Yes" of the questions (n = 12)			
	I can brush my teeth social story	Time to brush your teeth	A local published Chinese toothbrushing social story "刷牙社交故事"	TBVP (in-house developed)
Pediatric dentist 1	9	6	5	11
Pediatric dentist 2	9	7	7	9
Psychologist consultant	11	4	8	12
SCCC teacher 1	5	2	7	6
SCCC teacher 2	6	5	8	8
SCCC nurse 1	9	2	9	9
SCCC nurse 2	8	7	11	10
ASD child's parent 1	7	6	12	12
ASD child's parent 2	10	7	12	11
ASD child's parent 3	5	1	3	7
Total	79	47	82	95

Effects of the In-house Developed TBVP on Performance in the Task of Toothbrushing among Preschool Children with ASD

Written consents were obtained from the parents of 149 preschool children with ASD allocated in the intervention group. However, only 148 children (59.49 ± 10.69 months) were included in the study as one child failed to attend the toothbrushing evaluation at baseline. In the control group, preschool children with ASD were excluded if they only participated in the baseline assessment, or did not have toothbrushing evaluation at baseline assessment due to absence. Finally, 204 subjects (59.73 ± 8.97 months) were recruited in the control group, yielding an overall sample of 352 preschool children with ASD at baseline, ranged from 24 to 72 months of age. Among all 352 participants, 222 children (63.1%) completed the study and were assessed at baseline, 3 months and 6 months as shown in Fig. 2.

As shown in Table 6, for both the treatment and control groups, there were significant increase in the mean number of effective toothbrushing steps (step 5–9) that children were able to perform at 3 months compared to baseline ($p < 0.05$), and at 6 months compared to baseline ($p < 0.05$), but not between 3 and 6 months ($p > 0.05$). There was no significant difference in the mean number of effective toothbrushing steps (step 5–9) that children in the treatment and control groups were able to perform at baseline ($p > 0.05$). However, the mean number of effective toothbrushing steps (step 5–9) that children in the treatment group were able to perform was higher compared to children in the control group at 3 months ($p < 0.01$) and at 6 months ($p < 0.01$).

As shown in Table 7, there were significant changes in the proportion of children in both the treatment and control groups whose toothbrushing performance was rated *good/fair/poor* ($p < 0.001$) over time. For the treatment group, there were significant increase in the proportion of children rated *good* between 3 months and baseline ($p < 0.001$) as well as between 6 months and baseline ($p < 0.001$). However, no significant difference in ratings of performance of the toothbrushing task was observed between 3 and 6 months ($p > 0.05$).

Among the control group, there were significant increase in the proportion of children rated *good* between 6 months and baseline ($p < 0.001$) as well as between 6 and 3 months ($p < 0.05$). However, no significant difference in ratings was observed between 3 months and baseline ($p > 0.05$).

Discussion

Short written social stories with picture cues, or social story-based visual pedagogy have been developed in the past two decades to assist children with ASD in communication, mood management as well as learning life skills (Gray & Garand, 1993; Hagiwara & Smith Myles, 1999; Kokina & Kern, 2010; Kuoch & Mirenda, 2003; Pilebro & Bäckman, 2005; Sansosti et al. 2004; Zhou et al. 2020). The social story approach has proven effective as simple scripts together with direct picture cues can "enhance an individual's understanding of social situations and teach an appropriate behavioral response that can be practiced by the individual" (Sansosti et al. 2004).

Aligned with recent studies in terms of training children with ASD to learn toothbrushing through visual pedagogy (Al-Batayneh et al. 2019; Lopez Cazaux et al. 2019; Zhou et al. 2020), this study further provides evidence showing the effectiveness of the visual pedagogy aided toothbrushing learning program for preschool children with ASD. Additionally, the present study uniquely described the procedure for developing an in-house TBVP by incorporating feedback

Table 5 *Comments of review panel for the in-house developed TBVP*

	Strengths	Weaknesses	Suggestions
Pediatric dentist 1	(1) Clear sequential real-life pictures (2) Contain both English and Chinese descriptive writing (3) Contain close up photos of toothbrushing	None	(1) Should indicate the exact amount of tooth paste to be used
Pediatric Dentist 2	(1) Detailed brushing procedure	(1) There are too many things in the picture (e.g. the angry bird) (2) Readers may be too distracted (3) Too much information in one picture	None
Psychologist consultant	(1) Use of photos instead of drawn pictures (2) Very detailed steps presented (e.g. day and night concepts, picture of the magnified parts)	None	None
SCCC teacher 1	(1) With English and Chinese versions (2) Show messages with clear photos. (3) Show clear steps and directions of toothbrushing (4) Photos of a Chinese boy, good for local use	(1) Too many directive sentences especially in Chinese version (2) The angry bird picture may distract some of students' attention	(1) Should include more descriptive sentences and perspective ones (2) May consider wearing T-shirt without big angry bird (3) May consider deleting step 1, 2 and 3 (4) May consider adding a step to remind preparing toothpaste, toothbrush and cup for toothbrushing
SCCC teacher 2	(1) Had an introduction, body and conclusion (2) Perspective, descriptive sentences were included (3) Illustrations were clear	(1) The use of "I" at the beginning of each sentence of the toothbrushing steps could be cancelled, which made the story more reassuring (2) Add a topic to the story (3) The angry bird character on the T-shirt might be too attractive to some children. (4) The left and right direction of toothbrushing of the model was different from the reader, which might cause some confusion to the children)	(1) Good to add others perspective in the story (2) May simplify the toothbrushing by cancelling step 1, 3, and 12 (3) May consider deleting "I want to/ I can" ("我要/我會") at the beginning of each sentence of toothbrushing steps
SCCC Nurse 1	(1) Clean background (2) Basically smart-looking & clear illustrations, suitable for Asian children	(1) Can incorporate more perspective sentences	(1) Remove distracting prints on the child's t-shirt
SCCC Nurse 2	(1) There are English and Chinese version (2) The boy in the picture is adorable (3) The illustrative diagram of brushing each area gives a detailed information (4) Spiting of toothpaste and the water has been well-demonstrated in the picture	(1) The sentence is not that concise, but it can improve by omitting "I" "We" etc (2) The image of the boy is not big enough	(1) It would be favorable to have DVD and apps of this story
ASD child's Parent 1	(1) It is good enough	None	None
ASD child's Parent 2	(1) Good pictures with both large and small pictures for illustration (2) Steps are easy to follow. (3) I like this story the most	None	(1) More perspective/descriptive sentences should be included in the story
ASD child's Parent 3	(1) Using a "real boy" to demonstrate the brushing teeth step is more attractive for readers	(1) It covers all steps from beginning to the end, but it misses some critical steps, like gentle moving circle for front teeth; such that it can access the side of back teeth	(1) Brush front teeth using a gentle moving circle had not been mentioned

from a Review Panel, which was comprised of pediatric dentists, psychologist consultant, SCCC teachers, SCCC nurses and parents of children with ASD. It thus provides an informative reference for researchers and practitioners who intend to develop visual pedagogies and social stories for children with ASD in other aspects of early interventions. For instance, some researchers have used the method of visual cues and social stories to effectively promote autistic children's cooperation with regard to dental check-ups and fluoride therapy (Nilchian et al. 2017), communication skills (Adams et al. 2004; Ganz et al. 2008; Thiemann & Goldstein, 2001), verbal greeting initiations (Reichow & Sabornie, 2009), turn taking (O'connor, 2009), and social skills (Delano & Snell, 2006; Scattone et al. 2002; Swaggart et al. 1995).

In the process of developing TBVP, we followed the Review Panel's comments and modified the learning kit accordingly. The TBVP developed in-house was found to have the most relevant and feasible content as compared to the other three published social stories. Our TBVP is well aligned with the criteria for development of social stories as recommended by Gray and Garand (1993). Because of the content relevance and practical feasibility, teachers and parents of children in the treatment group easily integrated the TBVP program into the daily toothbrushing activity of children with ASD during the 6-month testing period. A significant improvement of the toothbrushing skills, in terms of the numbers of the toothbrushing steps and quality of toothbrushing performance, was observed statistically at 3-month and 6-month follow-up. This finding is in line with the study by Zhou et al. (2020) which showed that social story could be used as an intervention to improve the toothbrushing skills among children with ASD. Therefore, the null hypothesis was rejected. Children with ASD had improvement in toothbrushing skills after regular use of the TBVP aid.

Future Research Directions and Limitations of the Study

It is worth noting that during the evaluation of toothbrushing performance of preschool children with ASD at 3-month and 6-month follow-ups, two other major toothbrushing difficulties were observed in these children: swallowing a great amount of toothpaste and oral sensory sensitivity to brushing. The children with ASD in our study were between 2 and 6 years of age and they tended to swallow most toothpaste during brushing, which are usually observed in a typically developing child below the age of 3 years old (Buzalaf & Levy, 2011). This could be attributed to the impaired cognitive development of children with ASD (Annaz et al. 2010; Belmonte & Yurgelun-Todd, 2003; Bennetto et al. 1996; Landry & Bryson, 2004). Oral sensory sensitivity was also noticed in quite a number of children in our study, which aligns well with existing evidence that higher levels of oral sensory sensitivity was observed among children with ASD as compared with their typically developing peers (Chistol et al. 2018; Watling et al. 2001). The texture of the toothbrush, the taste of the toothpaste and the toothbrushing movement can easily trigger their oral defensiveness—which make it very difficult and frustrating for the caregivers to help the children with toothbrushing. Pre-brushing muscle massage and long-term desensitization have been suggested by the therapists to improve toothbrushing in children with ASD. We also interviewed the parents and collected their expectations on teaching toothbrushing in children with ASD. The parents would prefer the dentists to teach their children spitting out the toothpaste as well as to reduce their oral sensory sensitivities during toothbrushing. These could be the directions for future research to optimize the toothbrushing experiences of children with ASD.

One of the shortcomings include the constraints in achieving randomization. Ideally the participated children should have been randomly allocated into the intervention or control group. It was not able to accomplish due to the possibility of sharing the TBVP storybook within a SCCC. Also, as interventions were allocated by SCCCs, blinding of the outcome assessor and the participants could not be achieved completely, which might require cautious interpretation and further investigations of the current findings. The participating children in the study had different levels of oral hygiene status, family backgrounds and development profiles, which could have been the compound factors of the final outcomes in terms of oral hygiene and toothbrushing skill improvement.

In future research, a larger sample size should be obtained in order to evaluate the efficacy of the TBVP among children with ASD according to different subgroups based on their oral hygiene status, family backgrounds, and developmental profiles. More research is also warranted to explore the feasibility and effectiveness of applying social story and visual pedagogy as part of early interventions for children with ASD.

Conclusion

The 13-step toothbrushing visual pedagogy (TBVP) developed in-house helped the preschool children with ASD improve their toothbrushing skills in terms of the number of effective toothbrushing steps and the overall toothbrushing performance over a 6-month period.

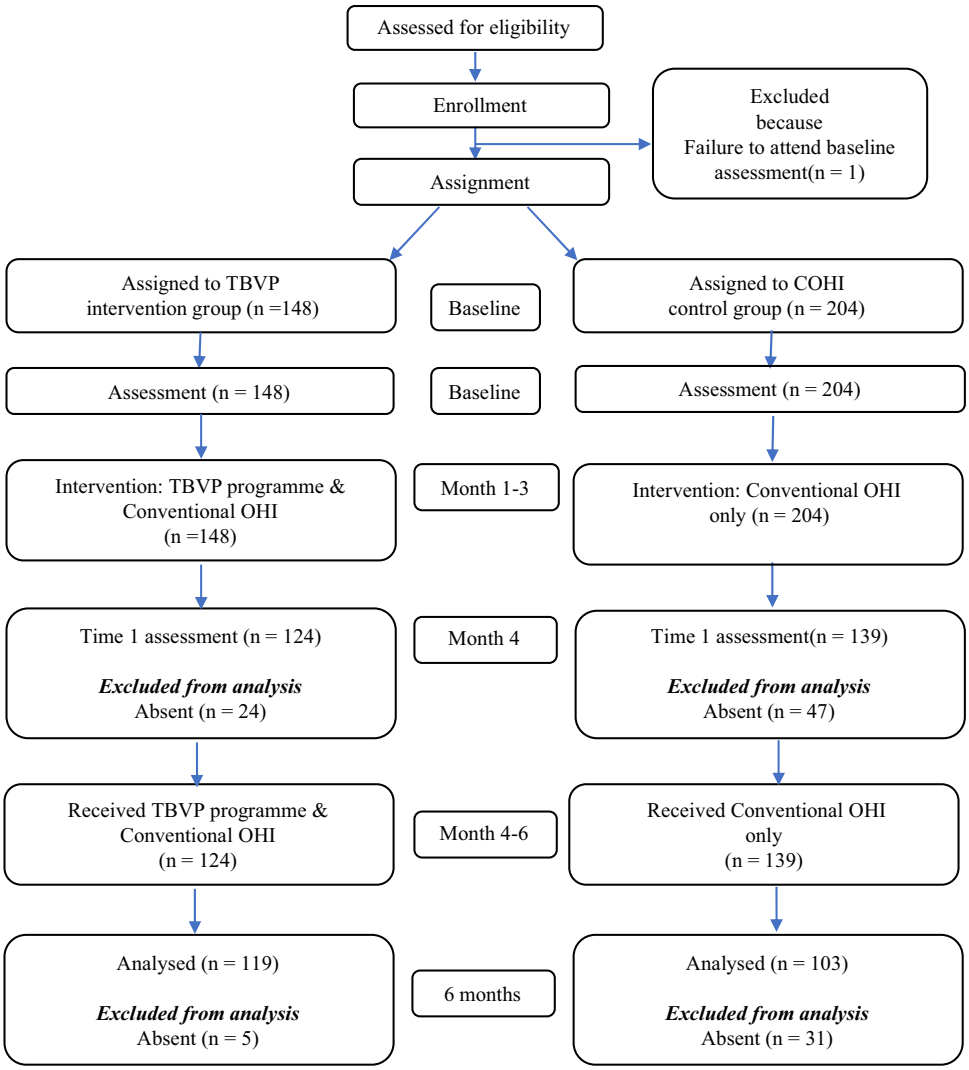

Fig. 2 Flow chart of the toothbrushing behavioral intervention study

Table 6 Performance in the toothbrushing and TBVP steps over time: inter and intra (n = 222)

	Baseline[a] Mean (SD)	3 months[b] Mean (SD)	6 month[c] Mean (SD)	*p*-value[†]
No. of effective toothbrushing steps [step 5–9]				
Treatment Group (n = 119)	1.88 (1.40)	2.69 (1.54)	2.87 (1.57)	< 0.001*** a < b (< 0.001), a < c (< 0.001)
Control group (n = 103)	1.59 (1.49)	2.12 (1.47)	2.22 (1.49)	< 0.001*** a < b (0.027), a < c (0.004)
p-value between groups[‡]	0.078	0.009**	0.003**	

[†] *p-values* derived from Related Samples Friedman's Two-Way Analysis of Variance by Ranks

[‡] *p-values* between groups derived from Mann–Whitney U test

*$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 7 *Rating of performance in the task of toothbrushing over time: inter and intra. (n = 222)*

	Baseline[a] % (n)	3 months[b] % (n)	6 month[c] % (n)	*p*-value[†]
Rating of toothbrushing task				
Treatment Group (n = 119)				
Good	32.8 (39)	51.3 (61)	58.8 (70)	< 0.001***
Moderate	17.6 (21)	20.2 (24)	13.4 (16)	a < b (< 0.001)
Poor	49.6 (59)	28.6 (34)	27.7 (33)	a < c (< 0.001)
Control Group *(n = 103)*				
Good	17.5 (18)	29.1 (30)	42.7 (44)	< 0.001***
Moderate	19.4 (20)	32.0 (33)	13.6 (14)	a < c (< 0.001)
Poor	63.1 (65)	38.8 (40)	43.7 (45)	b < c (0.018)
p-value between groups[‡]	0.031*	0.003**	0.034*	

[†] *p-values* derived from repeated measures *Cochrane Q test with Pairwise comparison based on the proportion of "Good"*

[‡]*p-values* between groups derived from *Chi Square tests*

[*]*p < 0.05, **p < 0.01, ***p < 0.001*

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Author Contributions RYD conceptualized, designed and conducted the study. RYD and WY drafted the initial manuscript and reviewed and revised all drafts of the manuscript. CKYY and CPM helped conceptualize the study and provided critical reviews of intellectual content. WY and PPYL provided critical reviews of the manuscript and ensured data represented in tables and text were accurate. All authors approved the final manuscript as submitted.

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