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ORIGINAL ARTICLE

Factors associated with toothbrushing performance among children: An observational cohort study

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Abstract

Background: Effective removal of dental plaque is essential factor for prevention of caries, gingival, and periodontal diseases in children and adults.

Aim: To evaluate factors associated with improving toothbrushing performance (TB-P) among children.

Design: An observational cohort study analyzed all paediatric patients receiving regular examinations in a single dental clinic between 2009 and 2017 and regularly brushing their teeth with a triple-headed toothbrush (TH-TB). At every periodic follow-up, the TB-P of the child/parent was evaluated using the TB-P Skill Index (TB-PS-I); that is, did the child reach all five teeth segments within each arch and did he/she perform 10 back-and-forth stocks in each segment. When not optimal, they received instructions for improving TB-P and subsequently were asked to re-demonstrate. TB-PS-I was calculated and analyzed for correlation with other explanatory variables.

Results: A total of 1737 children with 7399 follow-up appointments were analyzed. Older age, female gender, higher number of follow-up appointments, and compliance with twice-daily toothbrushing significantly improved TB-P. The most typical mistakes in their performance were not reaching the canine segments and not performing enough strokes in each segment. Instructions given after imperfect TB-P significantly improved the TB-P. The magnitude of improvement, however, did not correlate with the performers' age, gender, or the number of follow-up visits.

Conclusions: A significant percentage of children >8 years did not perform optimal toothbrushing even when using TH-TB.

KEYWORDS

age, children, oral hygiene instruction, parents, plaque, triple-headed toothbrush

1 | INTRODUCTION

Dental plaque is an essential etiological factor for caries, gingival, and periodontal diseases in children and adults.[1,2] Oral hygiene habits established early in life can improve lifetime dental and periodontal health.[3] Nevertheless, young children generally do not have good hand–eye coordination, and their frequency, consistency, quality, and duration of toothbrushing are lower than that of adults.[4,5] Moreover, the mean duration of toothbrushing was reported to be limited to 23–47 s in young children (3–11 years).[6,7]

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The manual triple-headed toothbrush (TH-TB, Dr. Barman, Dentaco AS, Norway) was designed to simultaneously clean all tooth surfaces (lingual, buccal, and occlusal) using horizontal scrubbing movements, thus improving the effectiveness and shortening the required duration of toothbrushing. Several studies have shown improved plaque removal, gingival, and bleeding indexes when using a TH-TB compared with using a single-headed brush in both normal and handicapped children, aged 4–15 years as well as among parents and caregivers who brush their children's teeth.[8–11]

Other studies evaluated the clinical efficacy of correct and effective toothbrushing using the TH-TB by examining the presence of plaque, caries, gingival and periodontal diseases.[12–14] These indices, however, do not elucidate the specific problems involved in toothbrushing nor indicate the best approach for educating patients on how to improve their children's toothbrushing performance (TB-P).[11] In children, accumulation of plaque can result from poor toothbrushing, due to lack of hand–eye coordination, brushing only a few tooth segments, not performing enough strokes in each segment, or due to lack of brushing teeth altogether.[10,11,15] Moreover, the estimated duration of toothbrushing does not always indicate the quality of the brushing especially if toothbrushing was performed only in a few segments of the arch.[7] Finally, most of the studies that evaluated the effectiveness of toothbrushing were cross-sectional studies with only a single evaluation of the TB-P after a single demonstration.[11] In a self-report cohort study, 4.5% of hygienists reported that they provided toothbrushing instruction only during the first meeting.[16] Notwithstanding, the importance of periodic evaluations of patients' TB-P is to identify and correct improper brushing, and to guide the patient on how to improve their TB-P, as well as to verify continuous correct performance. The TB-P Skill Index (TB-PS-I, Ashkenazi Index) was developed to evaluate the correct performance of toothbrushing during direct observation.[11] This index evaluates the TB-P skill according to two criteria: reaching all the teeth in each segment ("reach") and performing 10 horizontal strokes in each segment ("stay"). This index was negatively correlated with the plaque index.[10,11] The advantage of this index is it simplifies the instructions of toothbrushing for the patient in a comprehensible way while enabling the instructor to correct the patient according to their TB-P errors.

The aims of this study were to evaluate factors that influence the effectiveness of toothbrushing in children, evaluate the ability of consecutive periodic instructions to improve TB-PS-I, and identify typical errors in TB-P.

Why this paper is important to paediatric dentists

- TB-P of children is relatively low, even when using a TH-TB. Only 19%–32% of the children aged 6–7 years who brushed their teeth independently achieved perfect TB-P, even when using the TH-TB, which simplifies the task.
- The most typical mistakes in TB-P were in reaching the canine segments and not performing enough strokes in each segment.
- Increased number of follow-up appointments increase the use of higher concentrations of fluoride in toothpaste by children above age of 6 years.

In this study, our null hypothesis was that the effectiveness of toothbrushing in children when using TH-TB will not be affected by consecutive periodic instructions or by the age of the children. Moreover, parents who brush their child's teeth will show high effectiveness of toothbrushing, regardless of their child's age.

2 | MATERIALS AND METHODS

This study was performed according to the STROBE guidelines and was approved by the Ethics Committee of the Institution Review Board of the University of Alberta, Edmonton, AB, Canada (Pro00068968).

In this observational cohort study, all patients who attended follow-up appointments at a specialized paediatric dentist's clinic from September 2009 to November 2017 were initially included. During the first appointment, participants and their parents received a comprehensive structured lecture regarding the importance of maintaining good oral hygiene, preventive measures to practise regularly at home, and detailed information with a demonstration of toothbrushing techniques.

Each initial appointment included a comprehensive explanation of the importance of toothbrushing in preventing oral diseases. The primary focus was on preventing the buildup of dental plaque and reducing pathogenic bacteria. Patients were instructed to perform 10 horizontal strokes to remove plaque, use age-appropriate fluoride toothpaste, and apply toothpaste to all teeth before brushing to maximize fluoride exposure. Sensitive individuals were offered "Fluocaril" toothpaste (Fluocaril, Unilever, France). Instructions also

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covered the recommended amount of toothpaste based on age and the importance of not rinsing after brushing. Toothbrushing instructions emphasized the systematic coverage of all tooth surfaces and reaching the gingival margins. During follow-up appointments, patients demonstrated their brushing technique and received feedback. If necessary, guardians were enlisted to help with brushing until the next checkup.

The duration of the first appointment was 50–60 min, depending on the questions raised by the parents or children. The duration of each follow-up lasted about 20–30 min depending on the degree of compliance and TB-P of the patients. These instructions were provided by one paediatric dentist (M.A). Additionally, each parent was asked to estimate their past dental caries experience as low (scored 0), medium (scored 1), or high (scored 2). Accordingly, the range of both parents' caries risk scores ranged from 0 to 4 points. All patients were introduced to two manual toothbrushes (single-headed or triple-headed toothbrush [TH-TB] as well as an electrical toothbrush) and were instructed on how to use them correctly. All patients and parents who chose to brush their child's teeth with the TH-TB and their child attended at least one consecutive follow-up after the completion of their initial required dental treatments were included in this study analysis. During each periodic examination, the parents and their children were interviewed in respect of their children's daily oral hygiene habits. The parents and their children were asked to report how many days a week they brushed their teeth in the morning and in the evening, the concentration of fluoride in their child's toothpaste, and who regularly brushed their teeth. Immediately afterward, the child (or the same parent who brushed their teeth regularly) was requested to demonstrate optimal toothbrushing, according to the instructions provided at their previous appointment. When the TB-P was not optimal, they were given a demonstration of optimal TB-P on a plastic tooth model and on the child's teeth, while holding a hand mirror. Then, they were asked to re-demonstrate optimal toothbrushing according to the instructions they had just received (second evaluation). The evaluation of TB-P skill was scored according to two criteria: "reach" and "stay." "Reach" refers to the correct placement of the toothbrush on each of the five segments on the dental arch: right molars, right canine, incisors, left canine, and left molars. "Stay" refers to performing a sufficient number of horizontal strokes (10 strokes) in each segment. One point is awarded for each criterion performed, according to the instructions. Therefore, the maximum score was 20 points (10 points in each arch: 5 for reaching all five segments and 5 points for staying). When the children could not correctly perform toothbrushing after two demonstrations, their parents were instructed to brush their teeth routinely up to the next follow-up appointment.

2.1 | Statistical analysis

The overall TB-PS-I was calculated as the percentage of points achieved of the maximal possible points for the relevant technique.[10,11,16] Partial performance received a proportionally partial score. Descriptive statistics were performed at the children's level and the follow-up level.

The presence of calculus was also documented and correlated with the TB-PS-I.

Since several follow-ups were carried out for each child, a correlation might exist, which was accounted for in the analysis. The main outcome variable was the quality of toothbrushing according to the Ashkenazi Index with a range of 0–100.

To investigate possible correlations between TB-PS-I and other explanatory variables, the generalized estimating equation technique, which accounts for possible correlation within child measurements, was utilized. The normal probability distribution with an independent working correlation matrix was used. The significance level was set at 5%.

3 | RESULTS

Dental records of 1737 children who attended follow-up appointments at a paediatric dentist clinic were analyzed. The mean age of the children was 6.44 ± 3.96 years (range 0–18), with 51.6% boys. The age distribution of children at their first appointment is shown in Table 1. A total of 7399 follow-up appointments were conducted during the study period by one paediatric dentist. The distribution of children based on the number of follow-up appointments (1–20) is presented in Figure 1, with boys and girls, respectively having a mean of 4.02 ± 3.1 and 4.21 ± 3.6 follow-up appointments.

Self-report compliance of the children and their parents regarding their regular toothbrushing habits at home before coming to the check-up appointment.

Regarding toothbrushing habits, 77.7% and 78.9% of the children brushed their teeth regularly (6–7 days a week) in the morning and evening, respectively. A small percentage of the children (4.7% in the morning and 4.2% in the evening) brushed their teeth only 3–4 days a week, whereas 10.8% did not brush their teeth at all in the morning, and 8.1% did not brush in the evening.

Among the children, 54% brushed their teeth before breakfast, 37.7% after breakfast, and 8.3% reported not eating anything at home in the morning. No significant correlation was found between brushing before or after breakfast and the frequency of morning toothbrushing (ANOVA, $p = .707$).

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Based on the parents' reports of their past dental caries experience, 16%, 11.1%, 42.7%, 15.1%, and 15.2% were classified as having 0, 1, 2, 3, and 4 levels of caries risk, respectively. No significant correlation (by one-way ANOVA), however, was found between the parents' caries risk level and the frequency of their child's morning or evening toothbrushing ($p = .186$ and $p = .088$, respectively).

TABLE 1 Distribution of children's age at their first appointment.

Age (year)	Number of children	Percent of population
1	1	0.06
2	14	0.81
3	49	2.81
4	96	5.53
5	94	5.41
6	94	5.41
7	100	5.76
8	135	7.77
9	151	8.69
10	166	9.56
11	174	10.02
12	140	8.06
13	141	8.12
14	118	6.79
15	82	4.72
16	84	4.84
17	58	3.34
18	40	2.30
Total	1737	100.00

Despite detailed instructions during follow-up appointments, 4.7% of the children used toothpaste without fluoride, and 11.4% used toothpaste with a low concentration of fluoride (500–600 ppm F^-, Table 2). The increased number of follow-up appointments had a significant positive effect on the use of the correct concentration of fluoride in toothpaste ($p < .001$).

Among the children aged 6–7 years, 54.7% brushed their teeth independently, whereas this percentage increased to 83.6% among children aged 8–9 years (Table 3). Girls tended to brush their teeth independently more often than boys (49.8% vs. 45.3%, respectively). The mean age of children who brushed their teeth alone was 11.17 ± 4.09, whereas the mean age of children whose parents brushed their teeth was 6.175 ± 17.68.

The mean TB-PS-I score on the first evaluation was 78.89 ± 27.39 (median 95.0) during 3731 follow-ups of participants who had documented scores of 1–12 consecutive evaluations. The mean TB-PS-I score on the second evaluation was 89.79 ± 22.3 (median 100) during 1061 follow-ups of participants who had documented scores of 1–7 consecutive evaluations. Among the documented 898 follow-ups (of participants, who had 1–7 consecutive evaluations), with scores on both first and second evaluations, there was a significant improvement from the mean score on the first evaluation to the second evaluation 62.13 ± 25.1 versus 89.63 ± 22.64 (paired t-test, $p < .00001$; Figure 2). The mean score difference was $27.5 \pm 23.1\%$. On multivariate analysis, the magnitude of improvement was not correlated with the age or gender of the toothbrushing performer or the number of follow-up appointments.

The most common mistakes in toothbrushing during the first evaluation were related to "reaching" (69.3%–70.5% of the population) and "staying" (65.9%–66.8% of the population) at the right and left canine segments

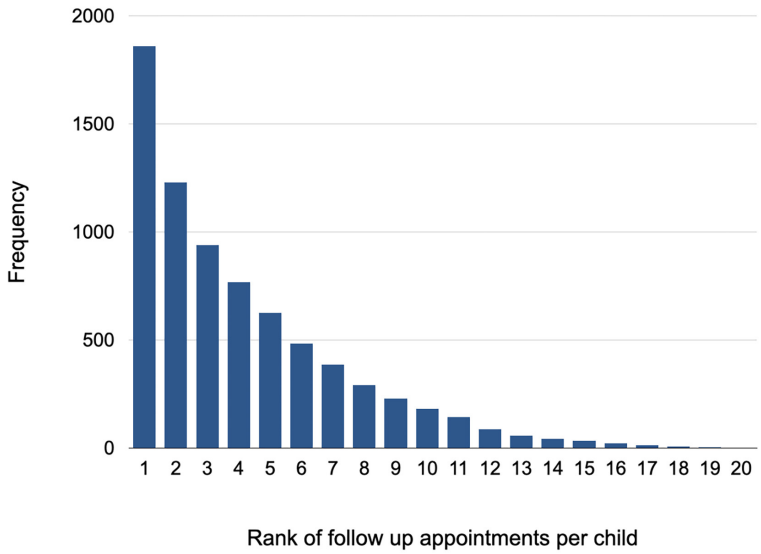


FIGURE 1 Distribution of children based on the number of follow-up appointments.

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TABLE 2 Using the correct concentration of fluoride in toothpaste in relation to the number of follow-up appointments.

Age of patients (year)	Number of follow-up	0% ppm F^-	400–500 ppm F^-	900–1000 ppm F^-	1400 ppm F^-	Total
0–6	1–2	63 (5.5%)	155 (13.4%)	736 (63.7%)	201 (17.4%)	1155 (100%)
	3–4	1 (0.2%)	24 (4.5%)	385 (72.8%)	119 (22.5%)	529 (100%)
	>5	0 (0%)	9 (2.7%)	211 (63.0%)	115 (34.3%)	335 (100%)
Total		64 (3.2%)	188 (9.3%)	1332 (66%)	435 (21.5%)	2019 (100%)
>6	1–2	5 (0.4%)	24 (2.1%)	84 (7.3%)	1037 (90.2%)	1150 (100%)
	3–4	1 (0.1%)	5 (0.5%)	53 (5.5%)	898 (93.8%)	957 (100%)
	>5	3 (0.1%)	3 (0.1%)	72 (3.5%)	1990 (96.2%)	2068 (100%)
Total		9 (0.2%)	32 (0.8%)	209 (5.0%)	3925 (94%)	4175 (100%)

TABLE 3 Distribution of who brushes the child's teeth according to age.

	Age group (years)				
Who brushes?	Age ≤ 5	Age 6–7	Age 8–9	Age > 10	Total
Parents	546 (74.6%)	64 (20.8%)	21 (9.9%)	7 (2.1%)	638 (40.4%)
Child	89 (12.2%)	168 (54.7%)	178 (83.6%)	313 (96.0%)	748 (47.4%)
Alone or parents	97 (13.3%)	75 (24.4%)	14 (6.6%)	6 (1.8%)	192 (12.2%)
Total	732 (100%)	307 (100%)	213 (100%)	326 (100%)	1578 (100%)

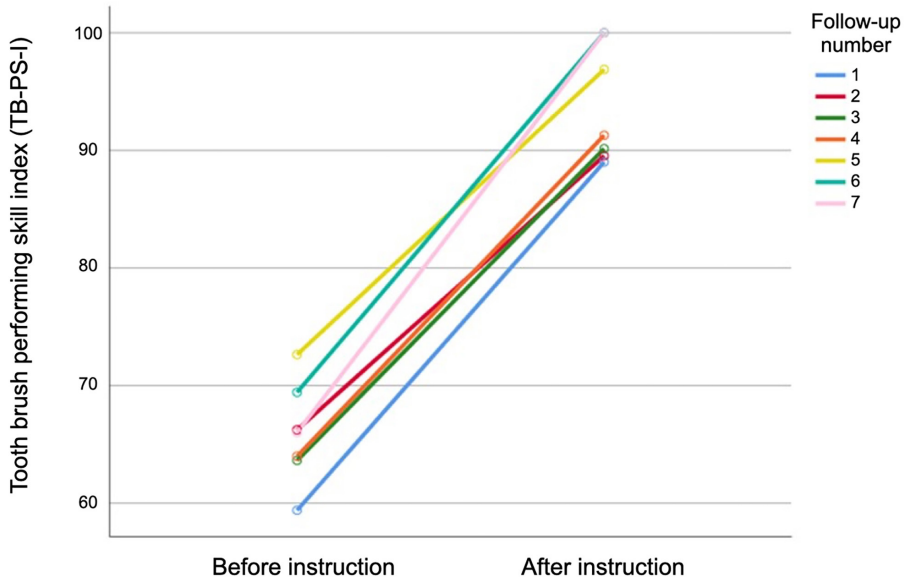


FIGURE 2 Mean Toothbrushing Performance Skill Index scores before and after instructions in relation to number of follow-up appointments.

(Figure 3). "Staying" at the incisor area (79%) and molar area (82.2%–82.8%) was also a prevalent error. More than half of children aged 6–12 years did not reach all their posterior teeth, whereas 15.7% of children over the age of 12 did not reach all their posterior teeth. On multivariate analysis, several factors influenced the TB-PS-I scores, including age, gender, number of follow-up appointments, frequency of toothbrushing at home, and parents brushing their children's teeth (Table 4).

Each year of age increased the TB-PS-I score on both evaluations, with a higher effect observed in the first evaluation (2% and 1.78%, respectively, $p < .0001$). In multivariate analysis, the effect of each year of age improved the TB-PS-I score of the first and second evaluations, respectively, by 37% and by 32%. It should be noted that only 32.1%, 66.8%, and 85.5% of children aged 8, 12, and 15 years, respectively, received a score of 100 in TB-PS-I, even though they used a TH-TB (Figure 4).

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FIGURE 3 Mean percent scores achieved in different components of Toothbrushing Performance Skill Index.

TABLE 4 Correlation between TB-PS-I and explanatory variables.

	First evaluation		Second evaluation		The magnitude of improvement after instruction	
	% Improvement	SE	% Improvement	SE	% Improvement	SE
Each year older	2.0*	0.1364	1.778*	0.28501	0.153	0.2302
Girls vs. boys	5.322*	1.3367	0.5016**	1.7388	2.135	1.7321
Parents vs. child brushing the teeth	4.446*	1.3155	4.402	2.4127	2.090	2.3928
Increased number of follow-ups	2.737*	0.1792	1.323***	0.6496	1.123	0.8348
Increased frequency of toothbrushing at home	1.521*	0.2710	0.17	0.3085	1.088*****	0.3288
Multivariance analysis						
Each year older	2.743*	0.1934	2.350*	0.3685		
Girls vs. boys	4.179*	1.1545	4.545	1.7479		
Parents vs. child brushing the teeth	23.206*	1.7617	15.996*	3.3351		
Increased number of follow-ups	1.581*	0.2109	0.806	0.6962		
Increased frequency of toothbrushing at home	0.858****	0.2606				

Abbreviation: SE, standard error.

*$p < .0001$; **$p = .004$; ***$p = .042$; ****$p = .001$; *****$p = .009$.

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Girls had higher TB-PS-I scores than boys in both evaluations (5.02% ± 1.74 higher, $p = .004$, Table 4). An increase in the number of follow-up appointments positively affected the TB-PS-I scores of the first and second evaluations ($p < .00001$) (Figure 2). Every follow-up appointment increased the TB-PS-I score of the first evaluation by 2.74%, $p = .00001$, and of the second evaluation by 1.32%, $p = .042$ (Table 4). In multivariate analysis, each additional consecutive follow-up increased the TB-PS-I score of the first evaluation by 1.58% and had no effect on the TB-PS-I score of the second evaluation.

The frequency of toothbrushing at home had a positive impact on the TB-PS-I score in the first evaluation. It was found that each additional day a week of toothbrushing increased the TB-PS-I of the first evaluation by 1.521% ($p = .0001$). In multivariate analysis, the effect of the increased frequency of toothbrushing at home on the TB-PS-I score of the first evaluation was increased by 0.858% ($p = .001$).

When parents brushed their children's teeth, their TB-PS-I scores were higher by 4.44% ($p < .0001$) during the first and by 4.40% ($p = .068$) during the second evaluation, as compared to the toothbrushing by children. Nevertheless, in multivariate analysis, the effect of parents brushing their children's teeth on TB-PS-I of the first evaluation increased by 530% and on the TB-PS-I score of the second evaluation by 360% (Table 4). Interestingly, parents' TB-PS-I scores were lowest when their children were up to 2 years old. Data regarding the presence of calculus on the lower incisors were documented in 3776 follow-ups. TB-PS-I of children and parents for "reaching" and "staying" in the lower incisors segment during the first evaluation was significantly higher in children with calculus on their lower incisors ($p = .043$ and $p = .025$, respectively), whereas no differences were found in the second observation (data not shown).

4 | DISCUSSION

The role of effective toothbrushing cannot be understated, as demonstrated by Axelsson et al.,[17] who showed that maintaining high-standard oral hygiene significantly reduced the incidence of caries, periodontal disease, and the need for tooth extraction over 30 years. Toothbrushing, however, is a complex task for both children and their parents, requiring eye–hand coordination, as well as the cognitive ability to understand the process.[6,11] The current study analyzed a large number of children's dental files in a real-world clinical setting, allowing for the examination of various factors associated with improved TB-P. Consistent with previous studies, we found that the children's TB-P declined six or more months after initial instruction.[11,16,18] Telishevesky et al.[11] demonstrated that 1 month after instructing parents to use the TH-TB for their children,

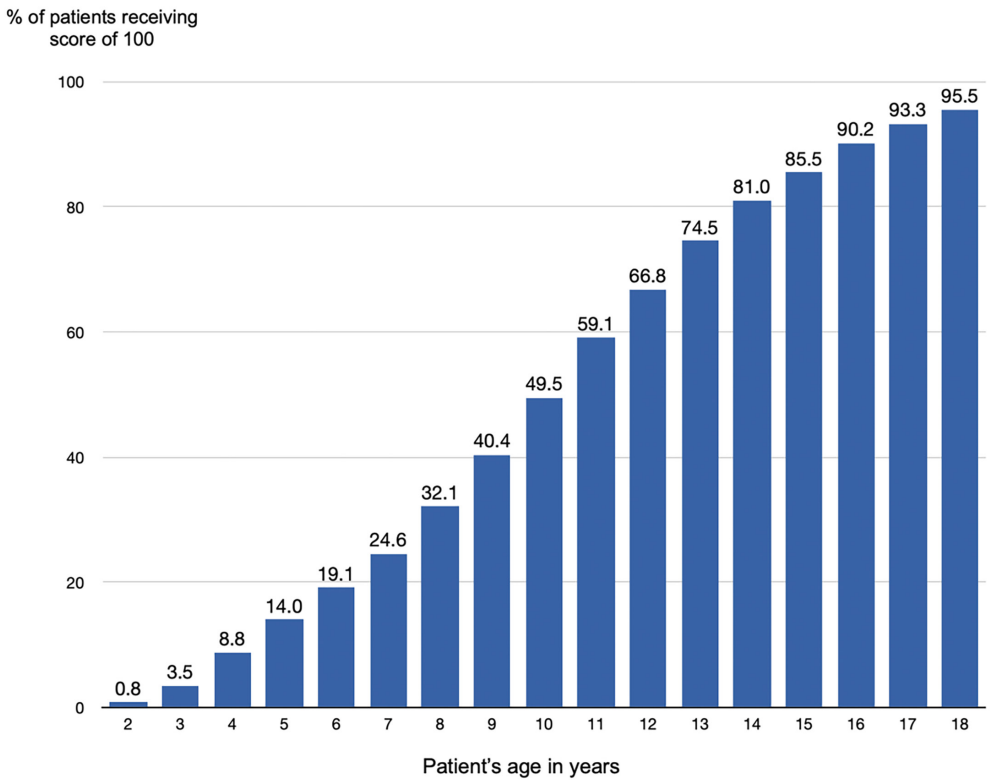


FIGURE 4 Percent of children receiving score of 100 on Toothbrushing Performance Skill Index in relation to age.

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there was no statistical decline in TB-P, suggesting that deterioration may occur later or primarily in children who brush independently.

Our findings revealed that the ability of children to improve their TB-P immediately following the instruction was correlated with their age and gender, with the frequency of toothbrushing at home also playing a role. These results highlight the importance of dentists re-motivating, re-evaluating, and re-instructing their patients during each follow-up appointment, rather than solely during the first visit. It should not be assumed that the level of oral hygiene observed during the initial dental checkup will be maintained over time.

The influence of gender on children's ability to perform toothbrushing was not surprising.[19,20] Notably, this study is the first to demonstrate the advantage of female gender on TB-P in young children and adolescents, even when using the TH-TB, which simplifies the task.[11]

Age also affected children's ability to improve their TB-P, consistent with previous studies, whether or not they used the TH-TB.[5,6] This finding highlights the importance of considering age as a factor, when evaluating TB-P, even with the use of the TH-TB.

It is worth noting that there were a few children who demonstrated perfect TB-P; nonetheless, they had poor gingival health and high plaque accumulation. These patients often admitted to not performing optimal toothbrushing at home. In such cases, instruction should primarily focus on motivation, rather than only on teaching the technique. This further underscores the importance of personalized instruction to maximize the effectiveness of dental guidance.

Interestingly, more than half (54.7%) of the children aged 6–7 years brushed their teeth independently, of whom only 19%–32% achieved perfect TB-P, even when using the TH-TB, which simplifies the task.[11] These findings contradict recommendations to allow school-age children from the age of 7 years to brush their teeth.[21] To facilitate effective and simple toothbrushing, toothbrush manufacturers are encouraged to develop tools that are easier to use.

The most common mistakes observed during toothbrushing were not reaching the canine area and not performing enough strokes in each segment. This aligns with Telishevesky et al.,[11] who also reported that parents tend to receive lower performance scores in the "stay" component than in the "reach" component. Notably, our study is the first to demonstrate that "reaching" the canine segment is significantly lower than other segments. Further research is needed to evaluate this finding using a conventional toothbrush. This finding suggests that when time is limited, evaluating plaque accumulation in the canine region, and reinforcing the child to perform 10 back-and-forth movements in each segment, is highly recommended.

Another interesting finding was that the TB-PS-I scores for "reaching" and for "staying" in the lower incisors segment, in children with calculus accumulation, were significantly higher during their first evaluation. The higher score may result from repeated attempts to remove the calculus from their lower incisors. These results may hint at a different etiology for calculus accumulation in the lower incisors in children, such as the presence of open bite.[22]

Another aspect of effective toothbrushing is the use of recommended concentrations of fluoridated toothpaste appropriate for the patient's age, under 6 years 1000 ppm and over 6 years 1450 ppm.[23,24] We found a positive correlation between an increased number of follow-up appointments and the use of higher concentrations of fluoride in children's toothpaste. This may be attributed to motivational interviewing techniques and the offer of toothpaste brands without menthol that contain 1400–1450 ppm F^- when children refused to use higher concentrations due to taste preference.[25]

The strength of our study is the high number of patients with a prolonged follow-up period, up to 9 years, reflecting real-life experience.

The limitation of the present study is that it was conducted in one dental clinic, and the toothbrushing was evaluated by one paediatric dentist. There may indeed differences between different clinics and between patient demographics, practice settings, treatment protocols, socioeconomic factors, etc. Therefore, our conclusions are limited to the dental setting described in this study. Additional studies in other locations, populations, and other dental settings are required to confirm our results.

In conclusion, daily toothbrushing at home and toothbrushing instruction can improve TB-P among children, yet a significant percentage of children older than 8 years still struggle to achieve optimal toothbrushing performance, even when using the TH-TB. These findings emphasize the importance of reassessing and re-instructing patients during each follow-up appointment.

AUTHOR CONTRIBUTIONS

VM and MY helped with the preparation of the data for statistical analysis, and analysis of data, were involved in writing the manuscript, and reviewed the manuscript. LL helped with the application to the institutional review board for approval, helped with the analysis of the data, and reviewed the manuscript. MA conceived the ideas, collected the data and prepared the data for statistical analysis, analyzed the data, and led the writing.

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CONFLICT OF INTEREST STATEMENT

All authors declare that they do not have any conflict of interest.

DATA AVAILABILITY STATEMENT

Research data are not shared.

ETHICS STATEMENT

This study was approved by the ethics committee of the institution review board (Pro00068968).

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