INTERNATIONAL JOURNAL OF PAEDIATRIC DENTISTRY

An application of the Health Action Process Approach model to oral hygiene behaviour and dental plaque in adolescents with fixed orthodontic appliances

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International Journal of Paediatric Dentistry 2017; 27: 486–495

Background. The Health Action Process Approach (HAPA) model addresses health behaviours, but it has never been applied to model adolescents' oral hygiene behaviour during fixed orthodontic treatment.

Aim. This study aimed to apply the HAPA model to explain adolescents' oral hygiene behaviour and dental plaque during orthodontic treatment with fixed appliances.

Methods. In this cross-sectional study, 116 adolescents with fixed appliances from an orthodontic clinic situated in Almere (the Netherlands) completed a questionnaire assessing oral health behaviours and the psychosocial factors of the HAPA model. Linear regression analyses were performed to examine the factors associated with dental plaque, toothbrushing, and the use of a proxy brush.

Results. Stepwise regression analysis showed that lower amounts of plaque were significantly associated with higher frequency of the use of a proxy brush (R^2 = 45%), higher intention of the use of a proxy brush (R^2 = 5%), female gender (R^2 = 2%), and older age (R^2 = 2%). The multiple regression analyses revealed that higher action self-efficacy, intention, maintenance self-efficacy, and a higher education were significantly associated with the use of a proxy brush (R^2 = 45%).

Conclusion. Decreased levels of dental plaque are mainly associated with increased use of a proxy brush that is subsequently associated with a higher intention and self-efficacy to use the proxy brush.

Introduction

In the Netherlands, one of three young people undergo orthodontic treatment[1]. The insertion of fixed orthodontic appliances (e.g., brackets) complicates dental cleaning and creates extra stagnation areas for plaque, which increases the amount of dental plaque[2]. Dental plaque is a causative factor for oral diseases, and thus, its removal and control are important aspects of oral health maintenance[3,4]. Prolonged plaque accumulation can lead to enamel demineralization and gingivitis, which are the common complications at treatment with orthodontic fixed appliances[5–8]. The severity of enamel demineralization can range from development of opaque white spots lesions, to loss of surface integrity of enamel and cavitation into dentine[9]. The prevalence of demineralization in orthodontically treated patients is higher compared to those without fixed appliances[5]. Richter *et al.*[9] showed that 72.9% of the patients developed at least one white spot lesion during fixed orthodontic treatment.

As part of usual dental care, instructions for removing dental plaque are given prior to and during orthodontic treatment in order to

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maintain good levels of oral hygiene[2]. These instructions are aimed at adequate toothbrushing and the use of dental aids, such as dental floss for interdental cleaning and proxy brushes (also known as interdental brushes) to clean around the brackets[2,10]. Nevertheless, it is estimated that in 5–10% of orthodontic patients, the appliances are prematurely removed before completion of orthodontic treatment, because of high levels of dental plaque caused by poor oral hygiene behaviour[11,12]. To optimize oral hygiene programmes aiming at reduction in dental plaque, it is important to understand the psychosocial factors that could be targeted by interventions. Knowledge about these factors is relevant as it creates an evidence base for the development of oral health promotion programmes[13].

A recent systematic review with meta-analysis provided some insight into psychosocial factors associated with the adolescents' oral hygiene behaviour[14]. It was shown that good oral hygiene behaviour was associated with 'action planning', 'coping planning', 'intention', and 'self-efficacy', factors that are part of a health behaviour change model: the Health Action Process Approach (HAPA). The HAPA model suggests that changing health-related behaviours comprises two consecutive behavioural phases: the motivational phase and the volitional phase[15]. The motivation (i.e., 'intention') to adopt health behaviour is formed by a growing 'risk perception', 'outcome expectancies', and 'action self-efficacy' (the motivational phase, see the left side of Fig. 1). A minimum level of perceived threat or concern must exist ('risk perception') before people start considering the benefits of possible actions ('outcome expectancies') and think about their competence to actually perform them ('action self-efficacy')[15]. Once intentions are formed, the volitional phase starts (see the right side of Fig. 1). The behavioural 'intention' has to be transformed into specific planning of when, where, and how to perform the desired action ('action planning') and planning of anticipated barriers and ways to overcome them ('coping planning'). Planning is strongly influenced by 'self-efficacy', because self-efficacious individuals achieve mastery through earlier planning, and they visualize successful scenarios that may guide goal attainment ('maintenance self-efficacy')[15].

Research has not provided a clear picture of the psychosocial factors associated with oral hygiene behaviour and dental plaque for adolescents who have received orthodontic fixed appliances treatment[14]. This study reports factors associated with oral hygiene behaviour and dental plaque in adolescents with fixed orthodontic appliances, for which we applied the HAPA model. The following question guided this cross-sectional study: 'To what extent are the psychosocial factors of the HAPA model associated with toothbrushing, the use of a proxy brush, and dental plaque levels in adolescents with fixed orthodontic appliances?'

Materials and methods

Participants and procedures

A sample of 116 adolescents (12–15 years) with orthodontic appliances were recruited from an orthodontic clinic situated in the city of Almere, the Netherlands. Adolescents with fixed orthodontic appliances with self-ligating brackets in both arches (which consisted of bonding of the teeth 16–26 and 36–46) were eligible for inclusion. Furthermore, patients were included if they were without mental and/or physical disabilities, craniofacial anomalies, enamel and/or dentin disorders, no missing teeth, no spacing or crowding greater than three millimetre, no removable or functional appliances, and no segmented bonding of fixed appliances. The following exclusion criteria were applied: (1) not able or willing to give informed consent; (2) insufficient command of the Dutch language; (3) the use of concomitant medication which may affect plaque accumulation, for example antibiotics and antibacterial mouth rinses within the last three months. When the fixed orthodontic appliances were inserted, a dental hygienist provided an oral health instruction to the patient using a leaflet with images. Approximately one month prior to the investigation, all adolescents visiting the

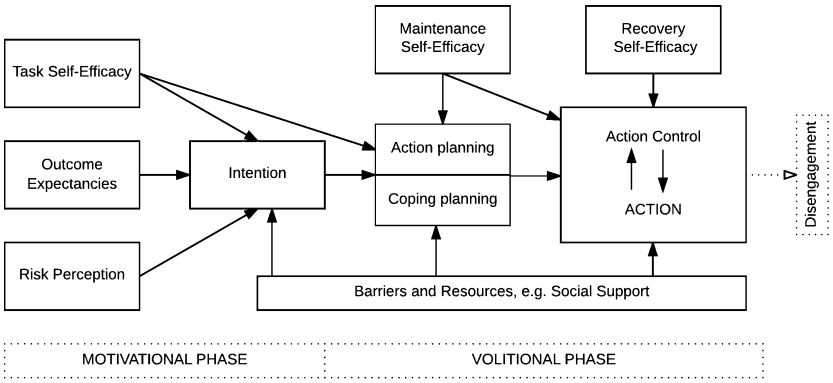

Fig. 1. The Health Action Process Approach model.[15]

orthodontic office were informed about the purpose of the study and invited to participate voluntarily. After having received informed consent from the adolescents and their parents or guardians, participants completed the questionnaire in the orthodontic clinic and a dental hygienist registered the dental plaque index. The Ethical Review Board of VU Medical Centrum (VUMC) Amsterdam approved the study (2016.162).

Clinical measurement

To assess the plaque on the buccal surfaces of the first molars, premolars, canines, and incisors, plaque disclosing agent was applied (Gum® Red-Cote® liquid) according to the instructions of the manufacturer. The buccal surfaces of each tooth were divided into four zones mesial, distal, gingival, and incisal to the bracket[16]. Each zone was given a score 0 (absence of plaque) or 1 (presence of the plaque). For the analysis, the percentage of zones covered with dental plaque was calculated.

Questionnaire

The self-administered questionnaire contained structured questions concerning oral health behaviours, psychosocial factors, and background information, such as gender, education level, ethnicity of adolescents and parents/guardians, and smoking status.

Questions concerning oral health behaviour were adapted from a questionnaire of Tolvanen *et al.*[17]. Respondents were asked to report the frequency of the use of, respectively, a toothbrush, a proxy brush, dental floss, toothpicks, and mouth rinse, using a seven-point scale ('1': less than twice a month or never, '2': twice a month, '3': once a week, '4': two to three times a week, '5': once a day, '6': twice a day and '7': three times a day or more frequently)[17]. For the analysis, these response alternatives were recalculated to describe the weekly frequencies of each of the oral health behaviour (ranging from 0 to 24.5; e.g., three times a day or more frequently was recoded into 24.5 by multiplying its frequency per day (3.5) by 7 days)[17]. Toothbrushing duration was measured by asking 'How much time do you spend on brushing your teeth at a time?' with eight-point scale (ranging in increments of 30 s from 0 to 4 min). For the analysis, the toothbrushing duration was multiplied by toothbrushing frequency to obtain a single item for the outcome toothbrushing behaviour (ranging from 0 to 89 min per week).

The questions concerning the psychosocial factors, 'risk perception', 'action self-efficacy', 'maintenance self-efficacy', and 'intention' were based on a questionnaire of Schwarzer *et al.*[18], and items for 'outcome expectancies', 'action planning', and 'coping planning' were adapted from previous studies on oral health[17,19]. All psychosocial factors were assessed using five-point scales, ranging from very low (1) to very high (5) for the item risk perception and ranging from totally disagree (1) to totally agree (5) for the remaining items. Item examples and psychometric data can be found in Table 1. Cronbach's alphas (α) (see Table 1) were calculated to estimate the lower bound of test–retest reliability. Acceptable values of Cronbach's alpha are

Table 1. Overview of variables and psychometric data.

Scales	Item example (range response alternatives)	No. of items	Response range	α
Outcome expectancies DC	If I clean my teeth regularly, my breath will be fresh. (totally disagree–totally agree)	6	1–5	0.89
Risk perception TB	If I do not brush my teeth frequently, the risk of caries will be... (very low–very high)	1	1–5	–
Risk perception PB	If I do not frequently use a proxy brush to clean my teeth around my braces, the risk of caries will be... (very low–very high)	1	1–5	–
Action Self-efficacy TB	I am confident that I can brush my teeth every day even when it is time-consuming. (totally disagree–totally agree)	4	1–5	0.79
Action Self-efficacy PB	I am confident that I can use a proxy brush every day even when it is time-consuming. (totally disagree–totally agree)	4	1–5	0.79
Intention TB	Over the next month I intend to brush my teeth at least twice a day. (totally disagree–totally agree)	1	1–5	–
Intention PB	Over the next month I intend to use a proxy brush to clean my tooth surfaces around the brackets daily. (totally disagree–totally agree)	1	1–5	–
Action Planning DC	I have made a detailed plan regarding when to clean my teeth. (totally disagree–totally agree)	5	1–5	0.90
Coping Planning DC	I have made a detailed plan regarding what to do if I forget to clean my teeth. (totally disagree–totally agree)	4	1–5	0.80
Maintenance Self-efficacy DC	I am confident I can maintain cleaning my teeth, even when it takes a long time to become part of my daily routine. (totally disagree–totally agree)	3	1–5	0.84
The frequency of use of a proxy brush	How many times have you used a proxy brush in the last 4 weeks? (never–3 times per day or more)*	1	0–24.5	–
Toothbrushing duration	How much time did you spend on brushing your teeth at a time? (<1 min–more than 4 min)**	2	0–98	–

DC, regarding dental cleaning; TB, regarding toothbrushing; PB, regarding proxy brush; α, Cronbach's α; *, responses were recoded into weekly frequency; **, responses were recoded into minutes per week.

reported to be 0.70–0.95[20]. The questionnaire is available upon request from the corresponding author.

Statistical analysis

Descriptive statistics were used to summarize the data. Independent sample t-tests were performed to test the differences in the number of zones covered with plaque between the posterior part and anterior part of the dentition of the maxilla and mandibular. One-way ANOVA with multiple comparison *post hoc* Tukey's tests was performed to test the differences in number of zones covered with plaque in relation to the various positions of the zones in relation to the bracket. To examine associations between the psychosocial factors and the outcomes, Pearson's correlation coefficients were calculated. The relative strength of psychosocial factors and oral hygiene behaviours as predictors of dental plaque was evaluated using a stepwise forward and backward selection procedure to construct a linear regression model[21]. The entry probability for each variable was set at 0.05. A linear regression with forced entry of all psychosocial factors was conducted to examine the predictive performance of the HAPA model on the frequency of use of a proxy brush and toothbrushing duration. Prior to the analysis, assumptions for linear regression analyses were checked, which revealed that the data were suitable for parametric analysis. SPSS Statistical Package for Social Sciences (IBM SPSS version 22.0, New York, NY, USA) was used to perform the statistical analyses.

Results

Descriptive statistics

A total of 116 (45% boys) adolescents with fixed orthodontic appliances, with a mean age of 12.8 years (SD = 0.64, ranging from 12 to 15 years) and a mean treatment duration of 9 months (SD = 5.8), participated in the study, giving a response rate of 82%. Of the study sample, 99.1% (all but one) was of

Table 2. Distribution of dental plaque according the zones to the bracket of the buccal tooth surface.

	Mean number (SD) of zones covered with plaque (max. 6)					
	Incisal to the bracket	Gingival to the bracket	Mesial to the bracket	Distal to the bracket	ANOVA *F* (*P*-value)	All zones
Maxilla – Anterior[a,b,c,d,e]	0.37 (1.03)	1.34 (2.13)	2.61 (2.83)	2.97 (2.70)	34.12 (0.001)	7.29 (7.14)
Maxilla – Posterior[a,b,c,f]	2.69 (2.04)	4.40 (1.76)	4.69 (1.90)	6.00 (1.53)	30.58 (0.001)	17.04 (5.75)
Mandibular – Anterior[a,b,c,e]	0.53 (1.18)	2.41 (2.44)	2.86 (2.84)	3.17 (2.75)	42.00 (0.001)	8.97 (7.68)
Mandibular – Posterior[a,b,c]	2.63 (2.16)	4.59 (1.73)	4.72 (1.80)	5.10 (1.48)	46.68 (0.001)	16.88 (5.95)

Anterior part of the dentition includes incisors and canines, and the posterior part includes first molars and premolars.
Significant at $P < 0.01$: [a], incisal *versus* gingival; [b], incisal *versus* mesial; [c], incisal *versus* distal; [d], gingival *versus* mesial; [e], gingival *versus* distal; [f], mesial *versus* distal.

Dutch nationality, 50% attended higher general secondary education or pre-university education, and 50% attended lower general secondary education. None of the respondents smoked. The mean dental plaque score was 52.5% (SD = 24.6); that is, on average, 50 of the 96 zones were covered by plaque. Table 2 presents the distribution of dental plaque accumulation according the zones to the bracket of the buccal tooth surfaces. The posterior part of the dentition (premolars and first molars) had significant higher amount of zones covered with plaque than the anterior part of dentition (incisors and the canines) in both the mandibular and maxilla ($P < 0.001$). Significant differences in plaque distribution were found between the four zones adjacent to the bracket. The distal zone had the highest mean plaque scores anteriorly and posteriorly in both arches (Table 2).

Intercorrelations between psychosocial variables, toothbrushing, the use of a proxy brush, and dental plaque, as well as means and standard deviations, are presented in Table 3.

Dental plaque was significantly negatively associated with all psychosocial variables except for 'risk perception' and 'intention regarding toothbrushing'. Self-reported toothbrushing and the use of a proxy brush were significantly and negatively associated with the dental plaque index. Toothbrushing was only significantly correlated with 'action self-efficacy', suggesting that higher self-efficacy was associated with increased toothbrushing. The use of a proxy brush was significantly correlated with 'risk perception', 'action self-efficacy', 'intention', 'maintenance self-efficacy', 'action planning', and 'coping planning'.

Psychosocial and behavioural factors associated with dental plaque

Table 4 presents the result of the stepwise multivariate linear regression analysis of psychosocial and behavioural factors to predict dental plaque in adolescents with fixed orthodontic appliances. The following factors, including background characteristics, were analysed as independent variables: gender, age, education, treatment duration, frequency of the use of proxy brush, toothpick and floss per week, toothbrushing duration per week, type of toothbrush, and the psychosocial factors with regard to toothbrushing duration and the frequency of the use of a proxy brush including 'risk perception', 'action self-efficacy', 'intention', and psychosocial factors with regard to dental cleaning including 'maintenance self-efficacy', 'action planning', and 'coping planning'. Forward and backward selection procedures revealed similar results. Stepwise multiple linear regression analysis showed that lower plaque indices were associated with more frequent use of a proxy brush ($\beta = -0.57$, $P < 0.001$), higher intention towards the use of a proxy brush ($\beta = -0.25$; $P = 0.001$), female gender ($\beta = -0.17$; $P = 0.011$), and older age ($\beta = -0.13$; $P = 0.043$). The total model accounted for 54% of the variance in dental plaque ($F(4, 111) = 32.91$; $P < 0.001$), of which the use of a proxy brush explained 44.7% of the variance, a positive intention towards the use of a proxy brush

Table 3. Intercorrelations between HAPA variables, the frequency of the use of a proxy brush, and toothbrushing duration.

Variables	Mean (SD)	OE-DC	RP-TB	RP-PB	ASE-TB	ASE-PB	I-TB	I-PB	AP-DC	CP-DC	MSE-DC	PB	TB	DP
Outcome expectancies of dental cleaning (OE-DC)	4.25 (0.73)	1.00												
Risk perception regarding toothbrushing (RP-TB)	1.51 (0.92)	0.03	1.00											
Risk perception regarding proxy brush use (RP-PB)	2.05 (0.92)	−0.13	0.47*	1.00										
Action Self-efficacy regarding toothbrushing (ASE-TB)	3.95 (0.71)	0.38*	−0.09	−0.16	1.00									
Action Self-efficacy regarding proxy brush use (ASE-PB)	3.58 (0.82)	0.33*	−0.07	−0.23*	0.73*	1.00								
Intention towards toothbrushing (I-TB)	4.53 (0.81)	0.20*	0.17	0.14	0.30*	0.16	1.00							
Intention towards proxy brush use (I-PB)	3.77 (1.11)	0.18	0.07	−0.17	0.31*	0.47*	0.37*	1.00						
Action Planning regarding dental cleaning (AP-DC)	3.76 (0.83)	0.28*	−0.04	−0.15	0.61*	0.38*	0.29*	0.28*	1.00					
Coping Planning regarding dental cleaning (CP-DC)	3.42 (0.73)	0.28*	0.03	−0.19*	0.58*	0.46*	0.18*	0.21*	0.52*	1.00				
Maintenance Self-efficacy regarding dental cleaning (MSE-DC)	3.91 (0.79)	0.33*	−0.10	−0.12	0.61*	0.40*	0.23*	0.26*	0.59*	0.55*	1.00			
The frequency of use of a proxy brush (times per week) (PB)	7.08 (7.28)	0.14	−0.01	−0.22*	0.38*	0.56*	0.10	0.47*	0.20*	0.28*	0.32*	1.00		
Toothbrushing duration (min per week) (TB)	24.21 (13.49)	0.01	−0.05	−0.05	0.29*	0.24*	0.08	0.16	0.13	0.10	0.08	0.23*	1.00	
Dental Plaque (%) (DP)	52.49 (24.56)	−0.22*	−0.03	0.19*	−0.41*	−0.52*	−0.15	−0.52*	−0.22*	−0.26*	−0.35*	−0.67*	−0.28*	1.00

*Correlation is significant at the level 0.05 (two-tailed) (n = 116).

Table 4. Stepwise multivariate linear regression analysis of psychosocial and behavioural factors to predict dental plaque in adolescents with fixed orthodontic appliances.

	Stepwise multivariate linear regression model			
Variables	**β (95% CI)**	**SE**	**R^2 change (%#)**	**R^2**
Frequency of the use of a proxy brush	−0.57 (−2.41; −1.44)*	0.25	0.45* (44.7%)	
Intention towards the use of a proxy brush	−0.25 (−8.67; −2.18)*	1.64	0.05* (5.4%)	
Gender (0 = male; 1 = female)	−0.17 (−15.09; −2.02)*	3.30	0.02* (2.4%)	
Age	−0.13 (−10.07; −0.16)*	2.50	0.02* (1.7%)	
				0.54 *

β, standardized regression coefficients; CI, confidence interval; SE, standard error; *$P < 0.05$; #, % variance explained.

explained an additional 5.4% of the variability, female gender explained 2.4% of the variance, and older age brush explained an additional 1.7% of the variance.

Additional analyses were performed to examine whether there were differences in psychosocial factors predicting the amount of dental plaque of the different zones of the dentition (posterior, anterior, mesial, distal, gingival, incisal, maxilla, or mandibular). These analyses did not reveal differences from the analyses with the total plaque index as a dependent variable (data not shown).

Psychosocial factors associated with the use of a proxy brush and toothbrushing

To examine predictive utility of psychosocial factors for the frequency of the use of a proxy brush (Table 5) and subsequently toothbrushing, multiple linear regression analysis was conducted. The multivariate model consisted of gender, age, education, treatment duration, risk perception, action self-efficacy, outcome expectancies, intention, maintenance self-efficacy, action planning, and coping planning. The regression equation significantly explained 45% of the variance in the use of a proxy brush ($F(11, 104) = 7.68$; $P < 0.001$) and 13% of the variance in toothbrushing ($F(11, 104) = 1.47$; $P = 0.16$). Higher action self-efficacy ($\beta = 0.38$ $P < 0.001$), intention ($\beta = 0.25$ $P = 0.005$), maintenance self-efficacy ($\beta = 0.21$ $P = 0.045$), and a higher education level ($\beta = -0.20$ $P = 0.012$) were significantly associated with a higher frequency of the use of a proxy brush. With regard to toothbrushing, only action self-efficacy emerged as a significant predictor ($\beta = 0.47$ $P = 0.002$).

Table 5. Linear regression of the frequency of the use of a proxy brush per week in relation to the HAPA variables as well as gender, age, education level, and treatment duration.

	Frequency of the use of a proxy brush			
	β (95%CI)	**SE**	**R^2**	**F**
Variables				
Gender (0 = male; 1 = female)	−0.09 (−3.56;0.95)	1.14		
Age	−0.04 (−2.19;1.26)	0.87		
Education level	−0.20 (−1.31;−0.16)*	0.29		
Treatment duration	−0.07 (−0.10;0.72)	0.10		
Risk perception	−0.08 (−1.78;0.59)	0.60		
Outcome expectancies	−0.03 (−0.32;0.21)	0.14		
Action Self-efficacy	0.38 (0.41;1.26)**	0.21		
Intention	0.25 (0.50;2,74)*	0.56		
Action planning	−0.18 (−0.64;0.03)	0.17		
Coping planning	0.03 (−0.40;0.56)	0.24		
Maintenance Self-efficacy	0.21 (0.01;1.25)*	0.31		
			0.45**	7.68**

SE, standard error; R^2, explained variance; F value (df1 = 11, df2 = 104).
*$P < 0.05$; **$P < 0.001$; ($n = 116$) β, standardized regression coefficients.

Discussion

Understanding the determinants of adolescents' oral hygiene behaviour during fixed orthodontic appliances therapy can help to plan oral health education and behaviour change interventions improving oral hygiene. In this study, we applied the HAPA model, to examine to what extent psychosocial factors

are associated with the amount of dental plaque, toothbrushing, and use of a proxy brush in adolescents with fixed orthodontic appliances. Results of stepwise multivariate linear regression analysis revealed that in this sample, dental plaque could be significantly predicted by the use of a proxy brush, intention towards the use of a proxy brush, gender, and age. Patients with low levels of dental plaque used the proxy brush more frequently. This could be explained by the fact that the approximal zones to the brackets are difficult to reach with a toothbrush, and the shape and size of a proxy brush allow cleaning these hard-to-reach areas. The association of the psychosocial factors (such as planning) with dental plaque was markedly attenuated after entering the variable the use of a proxy brush into the regression model. This suggests that oral hygiene behaviour mediates the association between psychosocial factors and dental plaque.

Higher action self-efficacy, intention, maintenance self-efficacy, and high education level were significantly associated with the use of a proxy brush and accounted for 45% of the variance in the use of a proxy brush. Merely 'self-efficacy' was significantly associated with toothbrushing, which accounted for 13% of the variance. The differences in variances found for these two oral hygiene behaviours could be explained by the fact that the use of a proxy brush requires more motivation than toothbrushing, as toothbrushing is a standard procedure for the general population and the use of a proxy brush to clean between the brackets is an additional recommendation for orthodontic patients. Another explanation is that other factors, such as 'self-determination', 'action control', and 'anticipated regret', play a role in explaining toothbrushing than the use of a proxy brush[14].

We hypothesized that 'volitional factors', such as 'action planning' or 'maintenance self-efficacy', would show the strongest associations with oral hygiene behaviour as postulated by the HAPA model (see also Scheerman *et al.*[14]). Our findings showed, however, that planning did not emerge as a significant predictor of oral hygiene behaviour in our sample. One could argue that measurement bias might have occurred, as the questions with regard to 'action and coping planning' were related to dental cleaning, which comprise both the use of a proxy brush and toothbrushing. Participants might have planned their toothbrushing behaviour, but not the use of a proxy brush, which makes it hard to answer the question whether they have planned to clean their teeth. Differences in the association of planning across oral hygiene behaviours were mentioned by a recent meta-analysis, which showed that 'action planning' was associated with toothbrushing, but not with flossing behaviour among 9- to 18-year-olds[14]. Future research should measure all psychosocial factors at specific behaviour level, that is toothbrushing separately from the use of a proxy brush, instead of combining all behaviours to one level (i.e., dental cleaning).

The study has some limitations that should be acknowledged. The sample may not be entirely representative of the Dutch 12- to 15-year-olds undergoing fixed orthodontic appliances. The conclusions cannot be generalized to adults wearing fixed braces, as the psychosocial factors may play a different role in adults[22]. Another limitation is that the self-report measures may be potentially biased and often inflated as a result of limitations in recall accuracy or social desirability. Furthermore, due to the cross-sectional nature of the study design, causal inferences cannot be made. This cross-sectional study provides evidence about potential mediators for planning interventions and provides an evidence base for improvement of intervention design by identifying putative determinants. A next step to verify the causal role of the psychosocial factors on oral hygiene behaviour and dental plaque levels during fixed orthodontic treatment is to examine them in intervention trials.

The results have implications for oral health promotion. Increasing the use of the proxy brush may allow for the greatest improvement in dental plaque accumulation. To increase the use of a proxy brush, oral health programmes could target 'intention' and 'self-efficacy' in performing the use of a proxy brush. This is in line with the results of Gholami *et al.*[23], who investigated the effectiveness of psychosocial variables in improving oral

hygiene targeting dental flossing in adolescents. They found that improvement of 'intention' and 'self-efficacy' by a brief self-regulatory intervention led to higher frequency of dental flossing after one month. Moreover, another study on university students revealed that three weeks after a brief self-regulatory intervention, participants with higher 'self-efficacy' were more engaged in oral hygiene behaviour[24]. Through application of strategies that target the psychosocial factors 'intention' and 'self-efficacy' interventional efforts might be stronger which may result in improved compliances with recommended practices. Guided practice could be a method to enhance 'action self-efficacy'[25]. Guided practice includes prompting individuals to rehearse and repeat the behaviour various times, discuss the experience, and provide feedback[25]. To achieve 'intention' formation, a method might include providing normative information about where and when others perform the behaviour, drawing persons' attention to others' performance (i.e., 'most young people clean their teeth in between the brackets with a proxy brush after toothbrushing every day')[23,27]. A method to enhance 'maintenance self-efficacy' could be self-monitoring, that is keeping records of their behaviours in form of a diary or checkmarks on a calendar[25]. This study shows the usefulness of the HAPA model in explaining oral hygiene behaviour in adolescents with fixed orthodontic appliances.

Why this paper is important for paediatric dentists

- This article provides information necessary for the planning of behaviour change programmes aimed to improve oral hygiene behaviour and dental plaque levels.
- Patients' intention and self-efficacy are most associated with oral hygiene behaviour in patients with fixed orthodontic appliances.
- The findings suggest that implementation of behaviour change techniques targeting patient intention and self-efficacy with regard to the use of a proxy brush might be promising to promote oral hygiene in adolescents with fixed orthodontic appliances.

Conflict of interest

The authors declare no conflict of interest.

Author contributions

J.S., P.E., and A.P. conceived the ideas; Z.M. and M.B. collected and entered the data; J.S. performed the analyses, P.E. and A.P. checked the analyses; J.S. wrote the manuscript, and B.M., C.L, A.P., MG, P.E., and G.V. led the writing.

References

1 Breuning H. Pubers en beugels. *Standby* 2010; **24**: 10–13.
2 Sudjalim TR, Woods MG, Manton DJ. Prevention of white spot lesions in orthodontic practice: a contemporary review. *Aust Dent J* 2006; **5**: 284–289.
3 Fejerskov O, Kidd E. Dental Caries: The Disease and its Clinical Management. Oxford: Blackwell Munksgaard, 2003: 189–222.
4 Shibly O, Rifai S, Zambon JJ. Supragingival dental plaque in the etiology of oral diseases. *Periodontol 2000* 1995; **8**: 42–59.
5 Øgaard B. Prevalence of white spot lesions in 19-year-olds: a study on untreated and orthodontically treated persons 5 years after treatment. *Am J Orthod Dentofacial Orthop* 1989; **96**: 423–427.
6 Zachrisson S, Zachrisson BU. Gingival condition associated with orthodontic treatment. *Angle Orthod* 1972; **42**: 26–34.
7 Travess H, Roberts-Harry D, Sandy J. Orthodontics. Part 6: risks in orthodontic treatment. *Br Dent J* 2004; **196**: 71–77.
8 Chapman JA, Roberts WE, Eckert GJ, Kula KS, González-Cabezas C. Risk factors for incidence and severity of white spot lesions during treatment with fixed orthodontic appliances. *Am J Orthod Dentofacial Orthop* 2010; **138**: 188–194.
9 Richter AE, Arruda AO, Peters MC, Sohn W. Incidence of caries lesions among patients treated with comprehensive orthodontics. *Am J Orthod Dentofacial Orthop* 2011; **139**: 657–664.
10 Bock NC, Von Bremen J, Kraft M, Ruf S. Plaque control effectiveness and handling of interdental brushes during multibracket treatment—a randomized clinical trial. *Eur J Orthod* 2009; **32**: 408–413.
11 Mehra T, Nanda R, Sinha P. Orthodontists' assessment and management of patient compliance. *Angle Orthod* 1998; **68**: 115–122.
12 Derks A, Kuijpers-Jagtman AM, Frencken JE, Van't Hof MA, Katsaros C. Caries preventive measures used in orthodontic practices: an evidence-based decision? *Am J Orthod Dentofacial Orthop* 2007; **132**: 165–170.
13 Michie S, Johnston M, Francis J, Hardeman W, Eccles M. From theory to intervention: mapping theoretically derived behavioural determinants to behaviour change techniques. *Appl Psychol* 2008; **57**: 660–680.
14 Scheerman JFM, Loveren C, Meijel B *et al.* Psychosocial correlates of oral hygiene behaviour in

people aged 9 to 19 – a systematic review with meta-analysis. *Community Dent Oral Epidemiol* 2016; **44**: 331–341.
15 Schwarzer R. Modeling health behavior change: how to predict and modify the adoption and maintenance of health behaviors. *Appl Psychol* 2008; **57**: 1–29.
16 Al-Anezi SA, Harradine NWT. Quantifying plaque during orthodontic treatment: a systematic review. *Angle Orthod* 2011; **82**: 748–753.
17 Tolvanen M, Lahti S, Miettunen J, Hausen H. Relationship between oral health-related knowledge, attitudes and behavior among 15–16-year-old adolescents—A structural equation modeling approach. *Acta Odontol Scand* 2012; **70**: 169–176.
18 Schwarzer R, Schüz B, Ziegelmann JP, Lippke S, Luszczynska A, Scholz U. Adoption and maintenance of four health behaviors: theory-guided longitudinal studies on dental flossing, seat belt use, dietary behavior, and physical activity. *Ann Behav Med* 2007; **33**: 156–166.
19 Pakpour AH, Hidarnia A, Hajizadeh E, Plotnikoff RC. Action and coping planning with regard to dental brushing among Iranian adolescents. *Psychol Health Med* 2012; **17**: 176–187.
20 Tavakol M, Dennick R. Making sense of Cronbach's alpha. *Int J Med Educ* 2011; **2**: 53.
21 Altham D. Practical Statistics for Medical Research. London: Chapman & Hall, 1991.
22 Albarracin D, Johnson BT, Fishbein M, Muellerleile PA. Theories of reasoned action and planned behavior as models of condom use: a meta-analysis. *Psychol Bull* 2001; **127**: 142.
23 Gholami M, Knoll N, Schwarzer R. A brief self-regulatory intervention increases dental flossing in adolescent girls. *Int J Behav Med* 2015; **22**: 645–651.
24 Schwarzer R, Antoniuk A, Gholami M. A brief intervention changing oral self-care, self-efficacy, and self-monitoring. *Br J Health Psychol* 2015; **20**: 56–67.
25 Kok G, Gottlieb NH, Peters GJY *et al.* A taxonomy of behaviour change methods: an intervention mapping approach. *Health Psychol Rev* 2015; **10**: 1–16.