Modelling Health Belief Predictors of Oral Health and Dental Anxiety Among Adolescents Based on the Health Belief Model: A Cross-Sectional Study

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Abstract

Background: A vicious cycle exists between dental anxiety, oral health behaviors and oral health status. Based on previous research, psychological factors of the Health Belief Model (HBM) are associated with oral health behaviors and oral health, and are likely involved in this cycle. However, little is known about the relationship between HBM factors and dental anxiety of adolescents. The purpose of this cross-sectional study was to investigate the relationship between health belief factors, oral health and dental anxiety based on the constructs of the HBM.

Methods: 1207 Grade 2 students from 12 secondary schools in Hong Kong were randomly selected and measured for the decayed, missing and filled permanent teeth (DMFT) index. Data for oral health behaviors, HBM constructs and dental anxiety were collected using questionnaires. The hierarchical entry of explanatory variables into logistic regression models estimating prevalence odds ratios (POR) were analyzed and 95% confidence intervals (95% CI) for DMFT and dental anxiety were generated. Path analysis was used to evaluate the appropriateness of the HBM as predictors for oral health behaviors, DMFT and dental anxiety.

Results: Based on the full model analysis, individuals with higher perceived susceptibility of oral diseases (POR: 1.33, 95% CI: 1.14-1.56) or girls or whose mother received higher education level were likelier to have a DMFT $\geq 1$, while those with higher perceived severity (POR: 1.31, 95%CI: 1.09-1.57), flossing weekly, DMFT $\geq 1$ or higher general anxiety level statistically increases the possibility of dental anxiety. The results from path analysis indicated that stronger perceived susceptibility, greater severity of oral diseases, less performing of oral health behaviors and a higher score of DMFT were directly related to increased dental anxiety level. Other HBM variables, such as perceived susceptibility, self-efficacy beliefs, cues to action and perceived barriers, might influence dental anxiety through oral health behaviors and caries status.

Conclusions: Clarifying the propositional structures of the HBM can help the future design of cognitive-behavioral therapy in reducing dental anxiety and preventing dental caries.

Background

A vicious cycle of dental anxiety, oral health behavior and oral health status has been hypothesized [1]. Multifaceted socio-economical and psychosocial aspects are involved in the onset of dental anxiety [1]. A 3-year cohort study demonstrated the crucial role of Decayed Missing Filled Teeth (DMFT) scores in the development of dental anxiety [2]. Psychological factors such as personality traits or attachment patterns are also important in the development and persistence of dental anxiety [3, 4]. Children with low psychological functioning tend to have higher levels of dental anxiety and increased social problems [3]. Moreover, self-rated oral health status can trigger dental anxiety which is mediated by certain cognitive vulnerabilities, such as threat or disgust [5]. Signs of depression and anxiety in adolescents [4], as well as higher psychological distress [6], are highly correlated to dental anxiety.
Dental anxiety among youth is a common problem in dental practice. The prevalence of dental anxiety among adolescents ranges from 9.4% to 19% [7]. Adolescence is a transitional phase from childhood to adulthood, with biological and psychological developmental changes occurring, such as social-networking [8]. In a retrospective study, 22% of respondents reported that their dental anxiety emerged in adolescence [9]. In establishing their health-related behavior and attitudes, dental avoidance in adolescents has the potential to influence their oral health in the short-term and long-term [10].

The Health Belief Model (HBM) is a theory which posits that one engages in particular health behaviors based on his belief towards susceptibility to illness and severity, and the perception that there are more benefits over barriers to taking action against illness [11, 12]. Previous research has found that the HBM can predict tooth brushing, flossing and dental visit behaviors [13, 14]. In addition, studies have demonstrated that stronger self-efficacy beliefs and greater perceived severity of oral diseases were related to increased tooth brushing frequency, which in turn was associated with better oral health status [15]. The HBM has also been applied in mental health and anxiety relief contexts [16]. Nevertheless, we are unaware of studies investigating the importance of HBM variables in oral health and dental anxiety contexts.

The objectives of the study were (a) to identify psychological factors contributing to oral health and dental anxiety based on the HBM and (b) to explore the direct and indirect associations of the HBM factors on oral health and dental anxiety via oral health behaviors among Hong Kong adolescents. To the best of our knowledge, this is the first study employing a theoretical model to explore HBM constructs involved in dental anxiety via oral health behaviors and oral health status. A well-known conceptual model of influences on health-related behaviors has been described by Janz and Becker et al [17]. Based on the previous model, we hypothesized that oral health beliefs (as conceptualized by HBM) involving higher susceptibility, greater severity, more barriers, fewer perceived benefits and weaker self-efficacy, would be associated with increased dental anxiety scores directly or indirectly through oral health behaviors and oral health status.

**Methods**

**Participants and Sampling**

The study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKW IRB) (IRB HKU: UW18–029). We hypothesized the prevalence of dental anxiety in the adolescent population as 19.5% based on previous studies [7]. The percentage frequency of the estimated dental anxiety was set at 19.5% with confidence limits of ± 2.5% and a significant level set at 5%. The sample size was calculated for 965 subjects. Accounting for an 85% response rate, 1136 subjects were required for recruitment. A list of government-funded secondary schools was retrieved from the official website of the Education Bureau, Hong Kong Special Administrative Region (http://www.edb.gov.hk). All secondary schools were coded respectively in the list of their district area (there were four districts of the Hong Kong SAR, i.e. New Territories West, New
Territories East, Kowloon and Hong Kong Island). Three schools were randomly selected from each of the four districts using the bowl method, given that there were approximately 100 Grade 2 students in each secondary school. The inclusion criterion included every Grade 2 student from the 12 invited schools. Students with severe systemic diseases, physical, or psychological disabilities were excluded. All eligible adolescents in the participating schools were approached. Written informed consents from parents were obtained prior to their child’s participation. The data were collected through self-reported questionnaires and clinical oral examinations from September 2018 to November 2018.

Measures

The questionnaire was filled by participants under the supervision of the teacher-in-charge in order to prevent student interaction and maintain data integrity. Age and the gender of participants were requested. The following oral health-related behaviors were measured: frequency of tooth brushing (1. Less than twice a day; 2. Twice or more a day), flossing frequency (1. Never or less than once a week; 2. Once or more a week), sugar consumption (1. Several times a week or daily; 2. Rare) and dental visits (1. No regular dental visit; 2. Have an annual dental visit). Each beneficial behavior scored 1 while discouraged behavior scored 0. The oral health behavior (OHB) score was calculated by summing up the scores of the four beneficial behaviors (ranged from 0–4), with a higher score indicating a higher level of oral health behavior.

The constructs of the HBM were measured using the OHBQAHBM, which consists of 35 items related to 6 interrelated components of the HBM; Perceived Susceptibility (2 items), Perceived Benefits (7 items), Perceived Barriers (6 items), Cues to Action (3 items), Perceived Severity (7 items) and Self-efficacy (10 items) [18]. Each item was scored on a scale from 1–5 points and the average score for each subscale was calculated thereby representing the individual’s belief towards that specific component. For each subscale, a higher average score indicates a stronger feeling towards its corresponding component.

Dental anxiety was assessed using the Modified Child Dental Anxiety Scale consisting of 8 questions [19]. Responses were scored from 1–5 points, giving a total score of 8–40. A higher score indicates a higher dental anxiety level. A score under 20 indicates no dental anxiety while a score equaling 20 or higher is indicative of dental anxiety [20]. General anxiety levels were measured using the Chinese version of the Generalized Anxiety Disorder–7 [21]. A 7-item self-rating questionnaire, each item is scored 0–4 points, giving a total range from 0 to 28. A higher score indicates a higher general anxiety level.

Two trained and calibrated dentists conducted dental examinations in schools using dental mirrors with added lights and Community Periodontal Index probes. Dental caries diagnosis was determined according to the criteria of WHO [22]. DMFT (number of decayed, missing, and filled teeth due to caries) score was calculated. To avoid measurement bias, the clinical examinations were performed unannounced in advance. 10% of children from each school were randomly selected and re-examined on the same day. Acceptable intra- and inter-examiner reliability was achieved (kappa = 0.90–0.94).

Data Analysis
The percentage of missing values of the questionnaire was 0.3–7.0%. For eligible participants, an MCAR (missing completely at random) analysis in SPSS was undertaken to test whether data were missing at random. The p-value for the MCAR analysis were all > 0.05, signifying that our data were missing completely at random. The expectation maximization algorithm was used to replace the missing values with predicted values.

Correlation tests confirmed weak associations among the HBM factors, oral health and dental anxiety (Spearman's Rho correlation range 0.1–0.4). Variables were not excluded due to collinearity. Using bivariate analyses, prevalence, corresponding confidence intervals, and p-values were generated using the ‘cross-tabulations’ approach in SPSS. Blocks of explanatory variables were entered into a binary logistic regression model using a hierarchical methodology, as predicated by our conceptual model (Figure 1). The dependent variable of these models were DMFT ≥ 1 or DMFT = 0 and the existence of dental anxiety. The HBM construct factors were entered into Model 1, with the main effects presented as prevalence odds ratio and 95% confidence interval (95% CI). The modifying factors were entered into Model 2 and oral health behaviors entered into Model 3. For DMFT, the full model (Model 4) comprised all factors. For dental anxiety, DMFT was entered into Model 4 and general anxiety entered into Model 5. The full model (Model 6) for dental anxiety comprised all factors. It is important to note that the full model was built based on a priori selection of covariates according to the conceptual model (Figure 1) as opposed to covariate selection based upon bivariate statistics. The degree of attenuation was calculated by the 1−[ln (adjusted OR)/ln (unadjusted OR)] formula [23]. A normality distribution test for general anxiety score, DMFT and HBM variables was used. Since the data were not normally distributed, a Mann-Whitney U test was used to compare the median between groups with dental with and without anxiety. The chosen level of significance was p < 0.05 (two-tailed). The above mentioned statistical analysis was conducted using SPSS 25.0.

To explore the relationship between HBM variables, general anxiety, OHB and DMFT, a path analysis was performed using AMOS 22.0. In this model, oral hygiene beliefs were posited to be related to dental anxiety both directly and indirectly through oral health behaviors and oral health status. If the p-value of the chi-square statistics ($\chi^2$) exceeded 0.05, the hypothesized path analysis was retained. The model fit was evaluated using multiple fit indices, such as the comparative fit index (CFI), goodness-of-fit index (GFI), Tucker-Lewis index (TLI), the root mean square error of approximation (RMSEA) and the standardized root mean squared residual (SRMR). Cut-offs to consider the model a good fit to the data were CFI > 0.90, TLI > 0.90, RMSEA < 0.06 and SRMR< 0.08 [24].

**Results**

**Sample Characteristics**

Of the 1207 eligible participants, 1159 participated in clinical examinations and returned questionnaires (response rate = 96%). The mean age of the participants was 14.32 ± 0.68 and the proportion of girls were 46.6%. The prevalence of dental anxiety among Hong Kong adolescents was 40.5%. Nearly half of
adolescents (45.0%) had a DMFT ≥ 1 (Table 1). 67.9% adolescents brushed their teeth at least twice a day, but only 20.3% flossed weekly. Most adolescents (81.7%) consumed sugar every week and less than a quarter (23.3%) had annual dental visitation plans. A high proportion of adolescents with DMFT ≥ 1 were girls with highly educated parents who had stronger perceived susceptibility of oral diseases and more perceived barriers towards performing OHB (Table 1). Dental anxiety among participants was associated with being a girl, lower flossing rates, higher sugar consumption rates, DMFT ≥ 1, stronger perceived susceptibility, stronger perceived severity, lower self-efficacy and higher general anxiety levels (Table 1).
Table 1
The relationship between dental anxiety and oral health behaviors, oral health status, HBM variables and general anxiety.

| Variable                   | Total group | DMFT=0 | DMFT≥1 | OR (95% CI) | No dental anxiety | Dental anxiety | OR (95% CI) |
|----------------------------|-------------|--------|--------|-------------|-------------------|----------------|-------------|
| Gender %                   |             |        |        |             |                   |                |             |
| Boys                       | 618 (53.4)  | 369 (57.9) | 250 (47.9) | 1            | 388 (56.6)       | 225 (48.2)    | 1           |
| Girls                      | 540 (46.6)  | 268 (42.1) | 272 (52.1) | 1.50 (1.19-1.89)* | 298 (43.4)       | 242 (51.8)    | 1.40 (1.11-1.77)* |
| Father's education level % |             |        |        |             |                   |                |             |
| Elementary school          | 84 (7.8)    | 39 (6.6) | 45 (9.3) | 1           | 49 (7.7)         | 35 (8.0)      | 1           |
| High school                | 741 (68.7)  | 400 (67.3) | 341 (70.3) | 0.74 (0.47-1.16) | 446 (69.8)       | 293 (67.0)    | 0.92 (0.58-1.45) |
| College or above           | 254 (23.5)  | 155 (26.1) | 99 (20.4) | 0.55 (0.34-0.91)* | 144 (22.5)       | 109 (24.9)    | 1.06 (0.64-1.75) |
| Mother's education level % |             |        |        |             |                   |                |             |
| Elementary school          | 128 (11.7)  | 54 (8.9) | 74 (15.0) | 1           | 74 (11.4)        | 54 (12.2)     | 1           |
| High school                | 740 (67.5)  | 410 (67.9) | 330 (66.9) | 0.59 (0.40-0.86)* | 444 (68.2)       | 294 (66.4)    | 0.91 (0.62-1.33) |
| College or above           | 229 (20.9)  | 140 (23.2) | 89 (18.1) | 0.46 (0.30-0.72)* | 133 (20.4)       | 95 (21.4)     | 0.98 (0.63-1.52) |
| Monthly family income %    |             |        |        |             |                   |                |             |
| HK$15,000 or below         | 183 (18.1)  | 91 (16.3) | 92 (20.3) | 1           | 106 (17.8)       | 77 (18.6)     | 1           |
|                            | 688         | 383     | 305     | 0.79        | 408              | 279            | 0.94        |
| HK$15,001-50,000 | (67.9) | (68.5) | (67.2) | (0.57-1.09) | (68.3) | (67.2) | (0.68-1.31) |
|------------------|--------|--------|--------|-------------|--------|--------|-------------|
| HK$50,001 or above | 142 (14.0) | 85 (15.2) | 57 (12.6) | 0.66 (0.43-1.03) | 83 (13.9) | 59 (14.2) | 0.98 (0.63-1.53) |

Tooth brushing behavior %

| Once a day or less often | 372 (32.1) | 201 (31.6) | 171 (32.8) | 1 | 210 (30.6) | 159 (34.0) | 1 |
|--------------------------|------------|------------|------------|---|------------|------------|---|
| Twice or more a day      | 787 (67.9) | 436 (68.4) | 351 (67.2) | 0.95 (0.74-1.21) | 476 (69.4) | 308 (66.0) | 0.86 (0.67-1.10) |

Flossing behavior %

| Never or less than once a week | 924 (79.7) | 503 (79.0) | 421 (80.7) | 1 | 530 (77.4) | 392 (83.9) | 1 |
|--------------------------------|------------|------------|------------|---|------------|------------|---|
| At least once a week           | 235 (20.3) | 134 (21.0) | 101 (19.3) | 0.47 (0.67-1.20) | 155 (22.6) | 75 (16.1) | 0.65 (0.48-0.89)* |

Sugar consumption %

| Rare or less than once a week | 212 (18.3) | 509 (79.9) | 438 (83.9) | 1 | 141 (20.6) | 69 (14.8) | 1 |
|-------------------------------|------------|------------|------------|---|------------|------------|---|
| Several times a week or daily | 947 (81.7) | 128 (20.1) | 84 (16.1) | 1.3 (0.97-1.78) | 545 (79.4) | 398 (85.2) | 1.50 (1.09-2.05)* |

Annual dental visit %

| No | 889 (76.7) | 478 (75.0) | 411 (78.7) | 1 | 520 (75.8) | 363 (77.7) | 1 |
|----|------------|------------|------------|---|------------|------------|---|
| Variable                        | Total group | DMFT = 0 | DMFT ≥ 1 | p    | No dental anxiety | Dental anxiety | p    |
|--------------------------------|-------------|----------|----------|------|-------------------|----------------|------|
| Perceived susceptibility (Mean ± SD)² | 2.65 ± 0.92 | 2.51 ± 0.91 | 2.82 ± 0.88 | <0.001 | 2.57 ± 0.92 | 2.76 ± 0.88 | < 0.001 |
| Perceived severity (Mean ± SD)² | 3.71 ± 0.88 | 3.73 ± 0.89 | 3.67 ± 0.86 | 0.24 | 3.65 ± 0.90 | 3.81 ± 0.82 | < 0.01 |
| Perceived benefits (Mean ± SD)² | 3.68 ± 0.59 | 3.68 ± 0.59 | 3.67 ± 0.58 | 0.54 | 3.67 ± 0.61 | 3.69 ± 0.54 | 0.60 |
| Perceived barriers (Mean ± SD)² | 2.27 ± 0.76 | 2.21 ± 0.75 | 2.35 ± 0.77 | 0.001 | 2.21 ± 0.76 | 2.37 ± 0.75 | < 0.001 |
| Cues to action (Mean ± SD)²    | 2.11 ± 0.91 | 2.10 ± 0.90 | 2.13 ± 0.94 | 0.90 | 2.12 ± 0.93 | 2.10 ± 0.89 | 0.82 |
| Self-efficacy (Mean ± SD)²     | 3.47 ± 0.99 | 3.50 ± 1.00 | 3.42 ± 0.99 | 0.27 | 3.55 ± 0.99 | 3.34 ± 0.99 | < 0.001 |
| General anxiety score (Mean ± SD)² | 4.81 ± 5.16 | - | - | - | 3.62 ± 4.65 | 6.56 ± 5.39 | < 0.001 |

| Variable                        | Total group | DMFT = 0 | DMFT ≥ 1 | OR (95% CI) | No dental anxiety | Dental anxiety | OR (95% CI) |
|--------------------------------|-------------|----------|----------|-------------|-------------------|----------------|-------------|
| Oral health (DMFT) %           |             |          |          |             |                   |                |             |
| DMFT = 0                       | 637 (55.0) | -        | -        | -           | 398 (58.0)        | 235 (50.3)     | 1           |
For an unadjusted model of HBM variables, every increase of one unit in perceived susceptibility resulted in 1.44 times the odds for DMFT $\geq 1$ (Table 2, Model 1). The addition of modifying factors to HBM variables attenuated the effect of perceived susceptibility on DMFT by 16% (Table 2, Model 2), while the addition of oral health behavior variables to HBM variables attenuated the odds by 10% (Table 2, Model 3). A strong perceived susceptibility persisted as a risk indicator for DMFT $\geq 1$ in the final model, which included all covariates. In the full model, the odds of perceived susceptibility was attenuated by 22% (Table 2, Model 4). In addition, girls and low education level of mothers were also significantly associated with DMFT $\geq 1$ in the full model (Table 2, Model 4).

*Note. P-value < 0.05

Note. Mann-Whitney U test was used given non-normal distribution.
|                          | Model 1 (POR, 95% CI) | Model 2 (POR, 95% CI) | Model 3 (POR, 95% CI) | Model 4 (POR, 95% CI) |
|--------------------------|-----------------------|-----------------------|-----------------------|-----------------------|
| Perceived susceptibility | 1.44 (1.25-1.65)*     | 1.36 (1.16-1.59)*     | 1.39 (1.21-1.61)*     | 1.33 (1.14-1.56)*     |
| Perceived severity       | 1.00 (0.87-1.15)      | 0.94 (0.80-1.11)      | 1.01 (0.87-1.16)      | 0.94 (0.80-1.11)      |
| Perceived benefits       | 0.98 (0.79-1.20)      | 1.05 (0.83-1.33)      | 0.97 (0.79-1.20)      | 1.05 (0.83-1.33)      |
| Perceived barriers       | 1.16 (0.97-1.39)      | 1.16 (0.95-1.42)      | 1.15 (0.95-1.39)      | 1.17 (0.94-1.46)      |
| Cues to action           | 0.96 (0.84-1.10)      | 1.00 (0.86-1.17)      | 0.98 (0.85-1.13)      | 1.02 (0.80-1.11)      |
| Self-efficacy            | 1.02 (0.89-1.15)      | 1.00 (0.87-1.16)      | 1.01 (0.88-1.16)      | 1.00 (0.86-1.17)      |
| Sex                      |                       |                       |                       |                       |
| Boy                      | -                     | 1                     | -                     | 1                     |
| Girl                     | -                     | 1.63 (1.25-2.12)*     | -                     | 1.65 (1.25-2.20)*     |
| Father's education level |                       |                       |                       |                       |
| Elementary school        | -                     | 1                     | -                     | 1                     |
| High school              | -                     | 0.76 (0.46-1.25)      | -                     | 0.72 (0.43-1.19)      |
| College or above         | -                     | 0.66 (0.37-1.21)      | -                     | 0.63 (0.34-1.15)      |
| Mother's education level |                       |                       |                       |                       |
| Elementary school        | -                     | 1                     | -                     | 1                     |
| High school              | -                     | 0.58 (0.38-0.89)*     | -                     | 0.60 (0.39-0.92)*     |
| College or above         | -                     | 0.56 (0.32-0.98)*     | -                     | 0.55 (0.32-0.98)*     |
| Family income per month  |                       |                       |                       |                       |
| HK$15,000 or below       | -                     | 1                     | -                     | 1                     |
| HK$15,001-50,000         | -                     | 1.00 (0.69-1.43)      | -                     | 1.01 (0.70-1.46)      |
In the unadjusted model, the increase in perceived susceptibility, perceived severity, perceived barriers and decrease in self-efficacy significantly resulted in a higher chance of dental anxiety (Table 3, Model 1). In the full model, only perceived severity remained significantly associated with dental anxiety. The odds of perceived severity and dental anxiety was 1.31, which was attenuated by 14% (Table 3, Model 6). The addition of modifying factors increased the effect of perceived severity by 4%, while general anxiety attenuated it by 19% (Table 3, Model 2&5). In addition, flossing behavior, DMFT and general anxiety were also associated with dental anxiety in the full model (Table 3, Model 6).

| HK$50,001 or above | - | 1.01 (0.61-1.68) | - | 1.04 (0.62-1.74) |
|-------------------|---|-----------------|---|-----------------|
| Tooth brushing behavior | | | | |
| Once a day or less often | - | - | 1 | 1 |
| Twice or more a day | - | - | 0.96 (0.73-1.28) | 0.92 (0.67-1.27) |
| Flossing behavior | | | | |
| Never or less than once a week | - | - | 1 | 1 |
| At least once a week | - | - | 0.99 (0.73-1.35) | 1.01 (0.71-1.42) |
| Sugar consumption | | | | |
| Rare or less than once a week | - | - | 1 | 1 |
| Several times a week or daily | - | - | 1.23 (0.69-1.26) | 1.10 (0.76-1.60) |
| Annual dental visit | | | | |
| No | - | - | 1 | 1.07 (0.76-1.51) |
| Yes | - | - | 0.93 (0.69-1.26) |
| -2 Log likelihood | 1558 | 1261 | 1508 | 1222 |
| Nagelkerke R² | 0.042 | 0.072 | 0.042 | 0.074 |

Note: *p < 0.05
Table 3
Multivariable models evaluating risk indicators for dental anxiety among adolescents

|                          | Model 1   | Model 2   | Model 3   | Model 4   | Model 5   | Model 6   |
|--------------------------|-----------|-----------|-----------|-----------|-----------|-----------|
|                          | (POR, 95% CI) | (POR, 95% CI) | (POR, 95% CI) | (POR, 95% CI) | (POR, 95% CI) | (POR, 95% CI) |
| Perceived susceptibility | 1.20 (1.04-1.38)* | 1.23 (1.05-1.43)* | 1.19 (1.03-1.37)* | 1.17 (1.02-1.35)* | 1.15 (0.99-1.33) | 1.16 (0.98-1.37) |
| Perceived severity       | 1.37 (1.17-1.59)* | 1.39 (1.17-1.65)* | 1.37 (1.17-1.60)* | 1.37 (1.18-1.59)* | 1.29 (1.10-1.51)* | 1.31 (1.09-1.57)* |
| Perceived benefits       | 1.06 (0.86-1.31) | 1.12 (0.89-1.43) | 1.04 (0.84-1.30) | 1.06 (0.86-1.32) | 1.05 (0.84-1.31) | 1.08 (0.84-1.39) |
| Perceived barriers       | 1.31 (1.09-1.57)* | 1.25 (1.01-1.53)* | 1.29 (1.06-1.57)* | 1.30 (1.08-1.56)* | 1.29 (1.07-1.56)* | 1.17 (0.93-1.48) |
| Cues to action           | 0.93 (0.81-1.08) | 0.95 (0.81-1.11) | 0.95 (0.82-1.09) | 0.94 (0.81-1.08) | 0.97 (0.84-1.12) | 0.99 (0.84-1.17) |
| Self-efficacy            | 0.84 (0.74-0.96)* | 0.80 (0.69-0.92)* | 0.87 (0.76-1.01) | 0.84 (0.74-0.96)* | 0.91 (0.79-1.04) | 0.92 (0.78-1.09) |
| Sex                      |            |            |            |            |            |            |
| Boy                      | -          | 1          | -          | -          | -          | 1          |
| Girl                     | -          | 1.42 (1.08-1.85)* | -          | -          | -          | 1.26 (0.94-1.69) |
| Father's education level |            |            |            |            |            |            |
| Elementary school        | -          | 1          | -          | -          | -          | 1          |
| High school              | -          | 0.95 (0.58-1.58) | -          | -          | -          | 1.04 (0.61-1.77) |
| College or above         | -          | 1.24 (0.68-2.26) | -          | -          | -          | 1.26 (0.67-2.37) |
| Mother's education level |            |            |            |            |            |            |
| Elementary school        | -          | 1          | -          | -          | -          | 1          |
| High school              | -          | 1.04 (0.68-1.59) | -          | -          | -          | 1.15 (0.73-1.82) |
|                      | College or above | Family income per month |HK$15,000 or below|HK$15,001-50,000|HK$50,001 or above|
|----------------------|------------------|-------------------------|------------------|----------------|------------------|
| Tooth brushing behavior |                  |                         |                  |                |                  |
|          |                  |                          |                  |                |                  |
| Once a day or less often | 1.13 (0.65-1.97) |                          | 1.09 (0.76-1.57) |                | 1.02 (0.62-1.70) |
| Twice or more a day   |                  |                          | 0.91 (0.68-1.21) |                | 0.74 (0.54-1.02) |
| Flossing behavior     |                  |                          |                  |                |                  |
| Never or less than once a week | 1.41 (1.01-1.96)* |                          |                  |                |                  |
| At least once a week  |                  |                          |                  |                |                  |
| Sugar consumption     |                  |                          |                  |                |                  |
| Rare or less than once a week | 1.13 (0.77-1.67) |                          |                  |                |                  |
| Several times a week or daily | 1.13 (0.77-1.67) |                          |                  |                |                  |
| Annual dental visit   |                  |                          |                  |                |                  |
|                 | No | - | - | 1 | - | - | 1 |
|-----------------|----|---|---|---|---|---|---|
| Yes             | -  | - | - | 1.08 (0.79-1.46) | - | - | 1.01 (0.70-1.45) |
| Model 1 (POR, 95% CI) | Model 2 (POR, 95% CI) | Model 3 (POR, 95% CI) | Model 4 (POR, 95% CI) | Model 5 (POR, 95% CI) | Model 6 (POR, 95% CI) |
| Oral health     |                |                |                |                |                |
| DMFT=0          | -  | - | - | 1 | - | - | 1 |
| DMFT≥1          | -  | - | - | 1.28 (1.00-1.63)* | - | - | 1.34 (1.01-1.79)* |
| General anxiety | -  | - | - | - | 1.11 (1.08-1.14)* | 1.11 (1.08-1.14)* |
| –2 Log likelihood | 1512 | 1245 | 1456 | 1508 | 1441 | 1151 |
| Nagelkerke R²   | 0.051 | 0.066 | 0.059 | 0.055 | 0.129 | 0.146 |

Note:*p < 0.05

Path Analysis Modeling

After deleting several insignificant paths, the final model is depicted in Figure 2 and as shown, the model was well fitted (TLI = 0.99; CFI = 1.00; RMSEA = 0.01; SRMR = 0.01; χ² = 13.60; df = 11; p = 0.26). Regarding the direct effect, a significant path was noted from general anxiety to dental anxiety (β = 0.44, p<0.01). Consistent with this hypothesis, higher perceived susceptibility (β = 0.56, p = 0.03) and greater perceived severity (β = 0.72, p<0.01) were associated with greater dental anxiety. Significant direct paths were also found to OHB from perceived susceptibility (β = −0.07, p<0.05), self-efficacy (β = 0.20, p<0.01), perceived barriers (β = −0.25, p<0.01) and cues to action (β = 0.08, p = 0.02). Regarding the direct effects of OHB and DMFT on dental anxiety, both were significant (β = −0.74, p<0.01; β = 0.28, p = 0.02).

For indirect effects exerted through OHB and DMFT, perceived susceptibility, self-efficacy beliefs, cues to action and perceived barriers were equal to 0.05 (SE = 0.03, p = 0.03), −0.16 (SE = 0.05, p<0.01), −0.06 (SE = 0.03, p<0.01) and 0.19 (SE = 0.07, p<0.01). The majority of standard errors of the unstandardized parameter estimates were small, indicating that values of the model parameters were estimated accurately.

**Discussion**

This study suggests that HBM factors are risk indicators for caries and dental anxiety among Hong Kong adolescents. After adjusting for socio-demographic factors and behavior covariates, the association of
perceived susceptibility with DMFT score and perceived severity in relation to dental anxiety was maintained.

We believe that this is the first study to examine the complex predictors regarding oral health and dental anxiety after accounting for the impact of HBM variables in a path analysis model of data. Our findings indicate that oral health beliefs (including HBM constructs) are associated with dental anxiety directly or indirectly via OHB and oral health.

In recent decades, pressure has been placed on therapeutics to reduce patients’ anxiety in the long term without pharmacological use [25, 26]. Psychological treatments have displayed better improvement in dental anxiety prevention in the long term compared to the use of pharmaceuticals [27]. In our study, we identified the role of HBM psychological constructs on the severity of dental anxiety. Threat-related perceptions based on past experiences may bring negative expectations of dental treatment and trigger dental phobia [28]. From the perspective of the HBM, threat perceptions are based on two beliefs: perceived susceptibility and perceived severity [29]. Perceived susceptibility refers to the chance of obtaining a disease or a painful state; perceived severity refers to one's belief towards the effect and psychological harm the disease could create [29]. In previous research on preoperative anxiety, perceived severity was a risk factor for increased anxiety levels [30]. In this study, perceived severity and perceived susceptibility were positively correlated with dental anxiety directly.

Other variables from the HBM are able to predict dental anxiety via the oral health behavior path. The HBM theory also proposes that if an individual has sufficient self-efficacy, perceived benefits over barriers, and cues to action, he is more likely to perform a behavior [29]. Dental anxiety is a risk factor for caries in younger children [23] and individuals with poorer oral health practices are correlated with higher dental anxiety levels [31]. Our study results were consistent with previous studies and the HBM variables indicate that they are related to dental anxiety via OHB and caries status.

Limitations

One of the major limitations of our study is the cross-sectional study design of the work. Given the nature of the design, a causal relationship between psychological factors and dental anxiety cannot be determined. Thus, future work is necessary to test this relationship using a longitudinal study design. Another limitation of our study is the use of self-reported measures. It is possible that response bias may limit the effects of our results. The third limitation of our findings is that it may not be generalizable to older adolescents as differences in psychological and physical status exist between early adolescents and late adolescents [32]. Regardless, the importance of the HBM in oral health and disease should be investigated further.

Conclusions

The present study suggests directions and further steps to be taken to reduce dental anxiety and improve oral health status in adolescents. The need for cognitive-behavioral interventions is further evidenced by
the fact that 2/3 of adolescents brushed their teeth as recommended (at least twice a day) but only 20.0% of adolescents flossed weekly. Most adolescents had a high frequency of sugar intakes and did not have plans for annual dental visitation. Moreover, our study found a relatively high prevalence of dental anxiety (40.5%) and DMFT ≥ 1 (45.0%). A high prevalence of dental anxiety has been shown to result in increased dental avoidance and poorer oral health outcomes. Our analysis of dental anxiety and oral health from a cognitive theory model perspective, such as the HBM, provides a clearer explanation for one of the mechanisms involved in oral health and dental anxiety among adolescents. Thus, there is a tangible application for the implementation of theory-based behavioral interventions targeting the promotion of oral health behaviors in schools as an alternative strategy in reducing dental anxiety and prevent oral diseases in adolescents.

List Of Abbreviations

HBM, Health Belief Model; DMFT, missing and filled permanent teeth; POR, prevalence odds ratios; CI, confidence interval; OHB, oral health behavior; CFI, comparative fit index; GFI, goodness-of-fit index; TLI, Tucker-Lewis index; RMSEA, the root mean square error of approximation; SRMR, the standardized root mean squared residual;

Declarations

Ethical approval and consent to participate

The study was approved by the Institutional Review Board of the University of Hong Kong/Hospital Authority Hong Kong West Cluster (HKU/HA HKW IRB) (IRB HKU: UW18–029). The mean age of the participants was 14.32 ± 0.68. Written informed consent from parents were obtained prior to their child’s participation.

Consent for publication

Not applicable

Availability of data and material

The datasets used and/or analyzed for the current study are available from the corresponding author on reasonable request.

Competing interest

The authors declare that they have no competing interests.

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Authors' contribution

BX: data collection, data analysis and writing of the manuscript. HMW: design of the study and revision of the manuscript. APP: critical review of the data analysis and results. CPJM: critical review of the manuscript. All the authors read and approved the final manuscript.

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Figures
Figure 1

Theoretical model for the study of the health belief model to predict oral health status and dental anxiety (Adapted from Janz & Becker, 1984 [17]).
Figure 2

Path analysis of psychological factors as predictors for dental anxiety. Standardized direct path coefficients are presented. Note. Significant differences indicated by ***p < 0.001; **p < 0.01; *p < 0.05.

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