

Review article

Effectiveness of psychological intervention in improving adolescents' oral health: A systematic review and meta-analysis

Isabella L. He, Pei Liu, May C.M. Wong, Chun Hung Chu, Edward C.M. Lo*

Institution: Faculty of Dentistry, University of Hong Kong, PR China



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ABSTRACT

Objectives: This systematic review aimed to evaluate the effectiveness of psychological interventions in improving oral health behaviors and status among adolescents.

Sources: A comprehensive search was conducted in the following six electronic databases, PubMed, Ovid Medline, Ovid Embase, Cochrane Library, APA PsycINFO (ProQuest) and Web of Science.

Study selection: The PICO format was used to select eligible studies. Population was adolescents 12 to 18 years old. Intervention was psychological interventions based on psychological theories or models. Comparison was conventional oral health education or negative control. Outcomes were oral health-related behaviors, oral health status, oral health-related quality of life (OHRQoL), self-efficacy and psychological cognitive factors. The risk of bias tool used was RoB 2.

Data: Sixteen papers on 14 studies met the inclusion criteria. The studies were conducted in school or clinic settings. Regarding risk of bias, most studies had some concerns and the others had a high risk. The psychological interventions improved adolescent's oral hygiene and periodontal status in the short-term (up to 6 months), with the overall SMD = -0.97 (-1.45, -0.49) in plaque level and SMD = -1.18 (-2.32, -0.04) in periodontal status. No significant difference in plaque level was found in the long-term (12 to 24 months), with the overall SMD = -0.31 (-0.64, 0.02). There was improvement in OHRQoL in the short-term, with the overall SMD = 1.04 (0.34, 1.73). Additionally, significant differences were found regarding self-efficacy, oral health-related behaviors (tooth brushing and dental flossing) and psychological cognitive factors between the intervention group and control group (all $p < 0.05$) in the short-term. Due to the heterogeneity of the studies, meta-analysis could not be conducted in the above three outcome measurements.

Conclusions: Low certainty of evidence shows that psychological intervention is effective in improving adolescents' oral hygiene in short-term. In addition, very low certainty of evidence was found in improving periodontal status, self-efficacy, oral health-related behaviors, psychological cognitive factors, and OHRQoL in short-term.

Clinical significance: By targeting the psychological process and cognitive factors of oral health-related behaviors among adolescents, psychological interventions have the potential to improve oral health behaviours and promote oral health among adolescents. Implementing evidence-based psychological interventions in dental practice can lead to more comprehensive and effective dental care for adolescents.

1. Introduction

Oral diseases affect the majority of adolescents globally. [1] Approximately 50 % of adolescents aged 12 to 15 years experienced dental caries in their permanent teeth with an increasing prevalence among those in developing countries. [2] Furthermore, gingivitis caused by plaque accumulation is also prevalent among adolescents. [3] Oral diseases have significant adverse effects on adolescents, including absence from school due to discomfort or treatment, impaired social

function (e.g., avoid smiling and teasing from classmates) and possible serious systemic health complications. These may have a significant and enduring influence, not just during adolescence but also for a long time even into adulthood. [4]

The common oral diseases are behavioral diseases. [5] Dental caries and periodontal diseases can be prevented by changing a person's lifestyle. [6] Dental caries in adolescents is closely related to the consumption of refined carbohydrates and sugar-containing drinks, while poor oral hygiene practices are related to both dental caries and

* Corresponding author.

E-mail address: edward-lo@hku.hk (E.C.M. Lo).

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periodontal disease. [7] Moreover, adolescence is thought of as the optimal period for cultivating favorable oral health behaviors, since habits developed during this period exhibit the greatest likelihood of being maintained into adulthood. [8] Therefore, it is important to implement effective interventions throughout this stage to develop proper oral health habits and prevent the occurrence of oral diseases throughout the person's life.

Conventional methods of oral health education (OHE) focus on the distribution of information and normative guidance which may not result in changing an individual's behaviors. [6] Previous research has demonstrated that acquiring more knowledge does not always lead to the development of a more positive attitude, [9] and the positive attitudes that are attained do not consistently improve the behaviors of individuals. [10,11] Modifying behaviors requires a comprehensive understanding of the psycho-social factors influencing people's social interactions, communication and development. [12–15] For adolescents, it is crucial to recognize the significance of their attitudes and beliefs regarding oral health behaviors as they are more concerned about the impairment of social interaction due to oral diseases compared to oral health per se. [12,16] Therefore, psychological interventions based on theoretical models are more preferable options for attaining sustainable behavior changes in adolescents. [17]

Previous studies have shown the usefulness of several psychological theories in guiding behavioral change and intervention, such as the Health Belief Model (HBM) [18], Social Cognitive Theory (SCT) [19], Health Action Process Approach (HAPA) [20], Motivational Interviewing (MI) [21] and Action Planning Model [22]. It has also been shown that combining HBM and SCT is effective in promoting adolescents' oral health behaviors, including tooth brushing and dental flossing at six-month follow-up. [23]

Results of systematic reviews show that some interventions based on psychological theories are effective in improving general health and related behaviors of people with chronic diseases, including dietary behaviors and physical activity among cancer survivors [24], medication adherence in patients with hypertension [25], chronic insomnia [26], mental well-being [27], eating disorders [28] and diabetes [29]. Psychological interventions are also effective in improving oral health-related behaviors, with self-efficacy, goal-setting, and planning being identified as key factors in modifying periodontal patients' behaviors. [30]

A systematic review conducted more than 10 years ago found that while some evidence showed that psychological interventions improved tooth brushing and self-efficacy, there was limited evidence on their effectiveness in reducing gingivitis or plaque in adults. [31]. In another systematic review on the effectiveness of behavioral interventions in promoting oral health among adolescents, moderate evidence in support of the efficacy of behavior interventions was found but some of the included behavioral interventions were not based on psychological theories. [32] Thus, there was a need for a new systematic review. The aim of the present systematic review was to evaluate the effectiveness of psychological interventions in improving oral health behaviors and status among adolescents. The main research question was "Are interventions based on psychological theories or models better than conventional oral health education or negative control in improving oral health among adolescents?"

2. Materials and methods

The present systematic review was registered in the international prospective register of systematic reviews PROSPERO (registration number: CRD42023489508) before conducting the literature search. The literature search was conducted in accordance with the principles specified in the Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) Statement. [33]

The literature search was performed in June 2023 on papers published after 1989. The databases searched included PubMed, Ovid

Medline, Ovid Embase, Cochrane Library, APA PsycINFO (ProQuest) and Web of Science. An updated literature search was conducted in June 2024. The identification of studies was conducted using search techniques specified in the Cochrane Handbook for Systematic Reviews of Intervention version 5.1.0. [34] Detailed search strategies are listed in Appendix 1. Grey literature, such as incomplete studies in databases like clinicaltrials.gov, was not searched. A manual search was conducted on the reference lists of all eligible papers to identify any additional relevant studies.

The pre-determined PICO framework is shown below:

Population: Adolescents 12-18 years old at baseline.

Intervention: Psychological interventions based on theoretical models aimed at improving adolescents' oral health.

Comparison: Conventional (prevailing) oral health education or negative control

Outcomes: Primary outcome was oral health status (e.g. oral hygiene, periodontal health status, and dental caries). Secondary outcomes included oral health-related behaviors (e.g. tooth brushing and dental flossing); psychological cognitive factors (e.g. health beliefs and attitude); self-efficacy; self-perceived oral health; and OHRQoL.

The inclusion criteria were papers on randomized trial with comparison group(s), published after 1 January 1990 and written in English. Studies were excluded if they met any of the following criteria: (1) intervention without using a psychological theory or model; (2) participants with systemic disease or receiving orthodontic treatment; (3) no relevant outcome measurements; and (4) insufficient sample size ($n < 40$).

The identified papers from the literature search was imported into EndNote, version 20.4.1 (Clarivate Analytics, Philadelphia, Pennsylvania, USA). After removing duplicates, two reviewers (ILH and PL) independently evaluated all titles and abstracts in accordance with the inclusion criteria. Full-text articles were obtained for further evaluation if they were thought probably relevant. For cases of disagreements between the two reviewers, they were resolved through discussion. If necessary, a third reviewer was consulted to reach a consensus. The reviewers followed the Cochrane guidelines to extract data from all eligible studies which ensured a standardized approach to data extraction and maintained consistency across the review process. [34] Information regarding authors, publication year, countries/regions, study design, sample size, data collection settings, implementation of intervention, outcome measures, and follow-up duration was put in a descriptive table. (Table 1)

Two independent reviewers assessed the quality of each included study utilizing a standardized critical appraisal instrument, Cochrane Risk of Bias Tool 2.0 (RoB 2), to rate the evidence and evaluate various domains or sources of bias in trial design, conducting and reporting that can affect the internal validity of a study. [35] Five domains were assessed: (1) randomization process, (2) deviations from the intended interventions, (3) missing outcome data, (4) measurement of the outcome, and (5) selection of the reported result. Evaluation of each domain was conducted according to specific criteria, and for each domain, the classification was 'low risk of bias', 'some concerns' or 'high risk of bias'. A study was assigned an overall low risk of bias if all domains were at low risk. A study was assigned as of some concerns overall if one or more domains had some concerns and no domain was at high risk. A study was assigned an overall high risk of bias if one or more domains were at high risk or multiple domains had some concerns.

The GRADE system was used to rate the level of evidence for each included outcome. [36] The items included risk of bias, inconsistency, indirectness, imprecision, and other considerations. The GRADE method categorizes evidence across studies in a systematic review into four levels: high, moderate, low, and very low, based on the quality and confidence in the estimate of the effect.

Table 1
Characteristics of included studies.

Author, (year) Place	Setting Age	Sample size	Study type	Follow-up	Intervention	Control	Outcomes
Dimenäs, et al., 2022, 2024 [39, 51] Sweden	Clinic-based 16 to 17 years	Test=158 Control=154	Prospective, multi-centered, two arm, quasi-randomized field study.	6-month	Person-centered education	Conventional education	<ul style="list-style-type: none"> • Plaque index • Marginal bleeding index • Frequency of tooth brushing • Frequency of interdental cleaning • Self-reported oral health status • Self-efficacy • Presence of disclosed plaque • Oral self-care skills • Oral self-care practice
Aleksejūnienė et al., 2022 [50] Lithuania	School-based 15 to 16 years	Test=97 Control=99	Cluster randomized controlled trial	6-month 12-month	Individualized education for each adolescent based on his/her needs for professional dental instruction.	One time preventive instruction, similar to what was commonly received in dental offices	<ul style="list-style-type: none"> • Frequency of tooth brushing and dental flossing • HBM/SCT constructs • OHRQoL • DMFT and VPI • Caries increment • Self-efficacy • Oral health behaviors (tooth brushing and snacking frequency)
Xiang, et al., 2022 [23] Hong Kong	School-based 13 years	Test=587 Control=572	Cluster randomized controlled trial	6-month 12-month	Six sessions delivered by selected peer leaders within 6 months, focusing on peer participation and social interaction.	Received booklets regarding oral health that were excluded from theory-based education.	<ul style="list-style-type: none"> • Plaque score • Oral health knowledge • Oral health behavior • Oral health literacy • Dental plaque index • PMT construct measures • Frequency of tooth brushing • VPI • CPI • Psychological cognitive measures • OHRQoL • Self-efficacy • Oral hygiene level
Wu et al., 2017, 2022 [37],[42] Hong Kong	School-based 12 to 13 years	Test 1= 163 Test 2=188 Control=161	Randomized controlled trial	6-month 12-month 24-month	Test 1: one-on-one face-to-face MI session, which lasted 15–30 min. Test 2: patient communication tool, Cariogram, was used at appropriate stages of the one-on-one face to-face MI session.	An oral health talk was delivered to all participants of each school. The talk lasted for about 30 min, including a 10-min session for raising questions. Each participant received an education package. No intervention	<ul style="list-style-type: none"> • Oral health knowledge • Oral health behavior • Oral health literacy • Dental plaque index • PMT construct measures • Frequency of tooth brushing • VPI • CPI • Psychological cognitive measures • OHRQoL • Self-efficacy • Oral hygiene level
Movaseghi Ardekani, et al., 2022 [38] Iran	School-based Only girls 14 to 15 years	Test =77 Control =85	Randomized controlled trial	1-month	Received four one-hour educational intervention sessions on knowledge, behavior, and oral health literacy based on the PMT framework.	No intervention	<ul style="list-style-type: none"> • Oral health knowledge • Oral health behavior • Oral health literacy • Dental plaque index • PMT construct measures • Frequency of tooth brushing • VPI • CPI • Psychological cognitive measures • OHRQoL • Self-efficacy • Oral hygiene level
Scheerman et al., 2020 [40] Iran	School-based 12 to 17 years	Test 1=253 Test 2=260 Control =278	Cluster randomized controlled trial	1-month 6-month	Content of the intervention based on the Health Action Process Approach (HAPA) delivered by the Telegram platform.	No intervention	<ul style="list-style-type: none"> • Oral health knowledge • Oral health behavior • Oral health literacy • Dental plaque index • PMT construct measures • Frequency of tooth brushing • VPI • CPI • Psychological cognitive measures • OHRQoL • Self-efficacy • Oral hygiene level
Aleksejūnienė, and Brukienė 2018 [41] Lithuania	School-based 12 to 13 years	Test 1=48 Test 2=52 Control =66	Cluster randomized controlled trial	3-month 12-month	Test 1: intervention guided by the Precaution Adoption Process Model (PAPM) Test 2: intervention guided by the Authoritative Parenting Model (APM).	Conventional dental instruction	<ul style="list-style-type: none"> • Oral self-care skills • Oral self-care practice • Frequency of tooth brushing • OHRQoL • Dental plaque • Periodontal status • Psychological cognitive measures • Dental plaque level
Džiaugytė, et al., 2017 [43] Lithuania	School-based 15 to 16 years	Test =73 Control =74	Cluster randomized controlled trial	6-month 12-month	Five individualized sessions facilitated by a dental professional.	One-time conventional dental instruction.	<ul style="list-style-type: none"> • Oral self-care skills • Oral self-care practice • Frequency of tooth brushing • OHRQoL • Dental plaque • Periodontal status • Psychological cognitive measures • Dental plaque level
Pakpour,et al., 2016 [44] Iran	School-based Mean age=15	Test 1=370 Test 2=372 Control =367	Cluster randomized controlled trial	1-month 6-month	Received leaflet and instructions. to form specific plans regarding brushing behavior.	Only received leaflet	<ul style="list-style-type: none"> • Oral self-care skills • Oral self-care practice • Frequency of tooth brushing • OHRQoL • Dental plaque • Periodontal status • Psychological cognitive measures • Dental plaque level
Aleksejūnienė et al., 2016 [45] Lithuania	School-based 15 to 16 years	Test =71 Control =68	Cluster randomized controlled trial	6-month 12-month	Three face-to-face educational hands-on sessions facilitated by a dentist and adolescents worked in pairs.	No intervention	<ul style="list-style-type: none"> • Oral self-care skills • Oral self-care practice • Frequency of tooth brushing • OHRQoL • Dental plaque • Periodontal status • Psychological cognitive measures • Dental plaque level

(continued on next page)

Table 1 (continued)

Author, (year) Place	Setting Age	Sample size	Study type	Follow-up	Intervention	Control	Outcomes
Gholami, et al., 2015 [46] Iran	School-based 11 to 15 years	Test =69 Control =97	Cluster randomized controlled trial	4-week	Received theory-guided materials on oral hygiene.	No intervention	<ul style="list-style-type: none"> • Frequency of dental flossing, • Intention to floss • Self-efficacy • Tooth brushing and flossing behaviors.
Pakpour et al., 2014[47] Iran	School-based Mean age =15	Test 1=124 Test 2=126 Control =122	Cluster randomized controlled trial	2-week 24-week	Test 1: received pamphlet with loss-framed messages Test 2: received pamphlet with gain-framed messages	No intervention	<ul style="list-style-type: none"> • Psychological cognitive measures • OHRQOL • Dental plaque • Periodontal status • Plaque level
Brukienė and Aleksejūnienė. 2012 [48] Lithuania	School-based 12 to 13 years	Test =72 Control 1=74 Control 2=75	Cluster randomized controlled trial	3-month 12-month	APM-based interventions included letters and telephone calls, and newsletters to parents	Control 1: Conventional dental education and behavior modification Control 2: Conventional behavior modification	<ul style="list-style-type: none"> • Plaque level
Aleksejūnienė and Brukienė 2012 [49] Lithuania	School-based 12 to 13 years	Test=89 Control 1=84 Control 2=81	Stratified randomized controlled trial	3-month 12-month	PAPM-based intervention	Control 1: conventional instruction Control 2: no intervention	<ul style="list-style-type: none"> • Plaque level

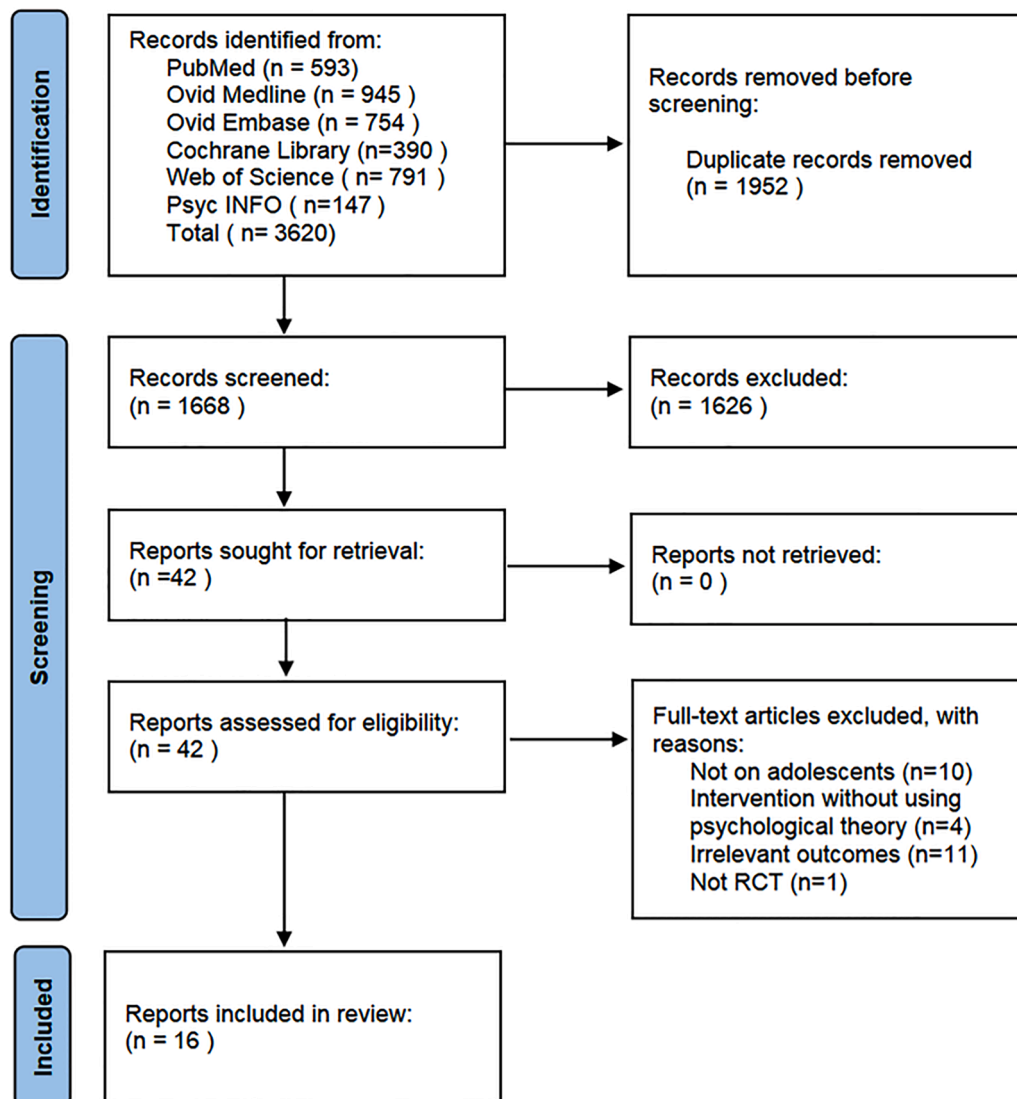


Fig. 1. Search flow chart for psychological intervention to improve adolescents' oral health status.

3. Data synthesis

A random effects model was employed to conduct a meta-analysis in RevMan (Version 5.4.1), considering the heterogeneity of the included studies, including study settings, intervention implementation and outcome measurements. For data to be synthesized in a meta-analysis, the RCTs addressing the same outcomes with sufficient data were used to calculate the overall effect size (standardized mean difference (SMD) and 95 % confidence interval (CI)) to compare the outcomes on oral health. The outcomes and time-points include:

- 1) Oral hygiene measured by Visual Plaque Index (VPI), % Oral Cleanliness Scores, Silness-Löe Plaque Index, and Individual Quantitative Plaque% Index (IQPI) at 6, 12, and 24 months follow-up.
- 2) Periodontal status measured by Community Periodontal Index (CPI) at 6 months follow-up.
- 3) OHRQoL measured by Pediatric Quality of Life Inventory (PedsQL) and the Child Perceptions Questionnaire (CPQ 11-14) at 6 months follow-up.

The effect of each study was weighted based on the adjusted effective sample size. Due to insufficient number of studies or inconsistencies in measurement standards, quantitative analysis could not be conducted for other outcome data. If a study comprised multiple interventions or control groups, the control and intervention groups were merged to conduct a single pair-wise comparison, following the guidelines outlined in the Cochrane Handbook. [34]

4. Results

The selection process is shown in Fig. 1. The search yielded 3620 items, and 1668 were evaluated after duplicates were removed. After screening the titles and abstracts, 1626 articles were deemed irrelevant and were removed. Thus, 42 full-text articles were accessed for eligibility. Finally, 16 papers on 14 studies were included in this systematic review and 12 studies were selected for meta-analysis. [23,37–51].

Studies conducted in four different countries or areas were included in this review, Hong Kong (n = 2), Sweden (n = 1), Iran (n = 5) and Lithuanian (n = 6), and the publication year spanned from 2012 to 2024 (Table 1). The number of participants in the individual studies ranged from 139 to 1184. Age of the participants were from 12 to 18 years. Gender distribution of the participants in most of the studies was even and in only one study, the participants were exclusively females. [46]

Psychological theory-based frameworks varied in the eligible studies, which included Health Belief Model (HBM), Social Cognitive Theory (SCT), Motivational Interviewing (MI), Planning Intervention, Health Action Process Approach (HAPA), Self-determination theory and Protection Motivation Theory (PMT) (Table 3 in the appendix). Most of the studies were conducted in school setting, with only one study in clinical setting. [51] The interventions used in the study varied in duration, ranging from a single session of 30 min [37] to multiple sessions in a period of six months [23]. The assessment time points also varied, ranging from immediate post-intervention [47] to 2 years follow-up [37].

Among the 14 studies, the risk of bias assessment showed that four of them had high risk of bias and ten with some concerns (Fig. 2). Most studies did not clearly state whether allocation concealment during the randomization process was maintained until participants were enrolled and underwent the intervention. Additionally, some studies failed to state whether baseline characteristics were comparable between the intervention and control groups. Moreover, for the outcome measurement, some of the studies did not mention whether the outcome assessors were aware of the interventions received by participants. In some studies, the assessment of outcomes may have been influenced by the knowledge of the intervention.

The primary and secondary outcomes of the studies are shown in Table 2 in the appendix. Eleven studies reported on the plaque index at 1 to 6 months follow-up. [38–45,47,49,50] Low level of evidence showed that psychological intervention could improve adolescents' oral hygiene in the short-term (up to 6 months) measured by various plaque indices compared to the control group, with the overall weighted SMD = -0.97 (95 % CI: -1.45, -0.49) (Fig. 3). Seven studies reported on the dental plaque level at the 12 to 24 months follow-up. [23,37,41–43,45,49,50] No significant difference was found between the psychological intervention group and the control group in long-term (12 to 24 months) follow-up, with the overall weighted SMD = -0.31 (95 % CI: -0.64, 0.02) (Fig 4). Since the 95 % CI of effect estimates crossed the minimally important difference (MID) of 0.1 and crossed the possibility of null effect (zero), indicating that the imprecision is very low, and the certainty of evidence was very low (Table 4 in the appendix).

Three studies reported on the periodontal status at 6 months follow-up using CPI. [40,44,47] All studies reported a better periodontal status of the participants in the intervention group at the follow-up, with the overall weighted SMD = -1.18 (95 % CI: -2.32, -0.04) (Fig. 5). Another study reported gingivitis status using the Marginal Bleeding index (MBI). In that study, it was found that at the 6 months follow-up, there was a

Study	D1	D2	D3	D4	D5	Overall		
Dimenäs, S. L., et al., 2024 & 2022 [39], [51]	!	+	!	-	+	-		
Xiang, B., et al., 2022 [23]	+	+	+	!	+	!	+	Low risk
Wu, L., et al., 2022 & 2017 [37], [42]	+	+	+	!	+	!	!	Some concerns
Movaseghi Ardekani, F., et al., 2022 [38]	!	+	+	-	+	-	-	High risk
Aleksejūnienė, J., et al., 2022 [50]	!	+	+	+	+	!		
Scheerman, J. F. M., et al., 2020 [40]	!	+	+	!	+	!		
Aleksejūnienė, J. and Brukienė, V. 2018 [41]	!	+	+	+	!	!	D1	Randomisation process
Džiaugytė, L., et al., 2017 [43]	!	+	+	+	+	!	D2	Deviations from the intended interventions
Pakpour, A. H., et al., 2016 [44]	+	!	+	+	!	!	D3	Missing outcome data
Aleksejūnienė, J., et al., 2016 [45]	!	+	-	+	-	-	D4	Measurement of the outcome
Gholami, M., et al., 2015 [46]	!	!	+	+	+	!	D5	Selection of the reported result
Pakpour, A. H., et al., 2014 [47]	!	+	+	+	-	-		
Brukienė, V. & Aleksejūnienė, J. 2012 [48]	!	+	+	+	!	!		
Aleksejūnienė, J. and Brukienė, V. 2012 [49]	!	+	+	+	+	!		

Fig. 2. Quality assessment of included studies by using RoB 2 assessment tool.

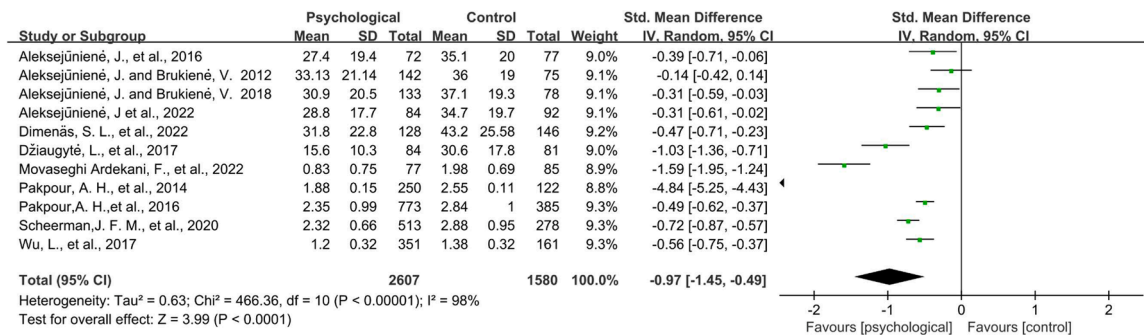


Fig. 3. Forest plot for the short-term psychological intervention's effectiveness on plaque index.

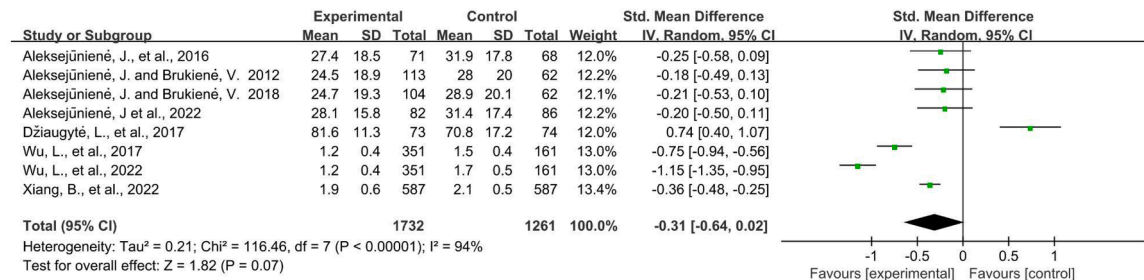


Fig. 4. Forest plot for the long-term psychological intervention's effectiveness on plaque index.

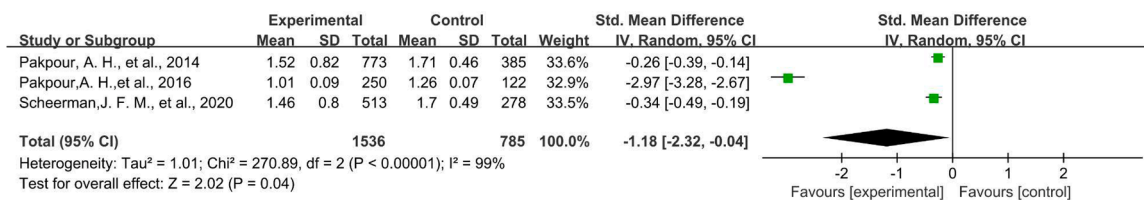


Fig. 5. Forest plot for the short-term psychological intervention's effectiveness on periodontal status.

higher proportion of participants in the intervention group with an MBI score ≤20 % compared with the control group. [39] The quality of evidence was very low (Table 4 in the appendix).

Three papers from two studies reported on the increment of dental caries in 1 to 2 years follow-up. [23,37,42] Both studies found that in the 12 months follow-up, the increment of cavitated lesions was lower in the intervention group compared with the control group. [23,42] The same result was found in one of the studies at 24 months follow-up. [37] Since there were only two studies, the certainty of the evidence was very low (Table 4 in the appendix).

Regarding oral hygiene practice, six studies reported on the frequency of tooth brushing and all of them showed that psychological intervention was more effective than the comparison group in improving adolescents' tooth brushing frequency in the short-term, up to 6 months. [23,39,40,42,44,47] Four studies reported on the frequency of dental flossing [23,39,46,47] and one of them only included girls. [46] All of the studies reported that psychological intervention was more effective than the comparison group in increasing adolescents' frequency of dental flossing in the short-term, up to six months. The quality of evidence was very low because the outcome measurement was inconsistent and the included studies had high risk of bias [39,47] or with some concerns [23,40,42,44,46] (Table 4 in the appendix).

Regarding self-efficacy on tooth brushing, two studies reported that compared with control group, participants in the intervention group had significant increases at 1 month, 6 months, 12 months and 24 months follow-up. [37,40,42] One study reported increase in self-efficacy on snacking habits for the intervention group at 6 months, 12 months and

24 months follow-up. [37,42] In another study, compared with the control group, intervention group had better self-efficacy on dental flossing at 1-month follow-up. [46] A study conducted in Sweden found adolescents in the intervention group reported higher confidence in maintaining good oral hygiene compared to those in the control group. [51] Due to the heterogeneity of the questionnaires on self-efficacy regarding tooth brushing, dental flossing and sugar intake, meta-analysis was not conducted. The overall quality of evidence was very low (Table 4 in the appendix).

Regarding the psychological cognitive factors that may influence oral health behaviors, seven studies reported changes in the factors based on the theoretical models they used. [23,38,40,44,46,47,50] All the psychological factor measurement methods were through self-reported questionnaires but only two studies used validated questionnaires. [23,38] All seven studies showed that psychological intervention based on theory models resulted in significant improvements in psychological cognition in short-term follow-up (1 to 6 months). However, only one study reported on long-term effectiveness of psychological intervention, and significant differences in mean gain scores were found between the intervention and the comparison groups at 12 months follow-up for perceived barriers, perceived severity, and behavioral capability. [23] Since the heterogeneity of the included studies was very high, the certainty of the evidence was very low (Table 4 in the appendix).

Four studies reported on the OHRQoL in 6 months follow-up. [23,40,44,47] Compared to the control, at 6 months, psychological intervention groups had a larger change score in OHRQoL with a weighted SMD of

1.04 (95 % CI: 0.34, 1.73) (Fig. 6). All four studies only reported the overall OHRQoL score without reporting on the effectiveness of psychological intervention on specific domains, such as physical, emotional, social, and school functioning. Moreover, none of the studies explored the long-term effectiveness of psychological intervention in improving adolescents' OHRQoL. The level of evidence was very low (Table 4 in the appendix). In addition, one study found that after six months, the intervention group had a better self-reported oral health status than the control group, indicating that the theory-based approach was more effective than traditional oral health education. [51]

5. Discussion

This systematic review included 16 papers from 14 randomized control trials. To the best of our knowledge, it is the first systematic review and meta-analysis which focuses on the effectiveness of behavioural interventions based on psychological theory models in improving adolescents' oral health status and behaviours. Results of the present review show that psychological intervention is effective in improving adolescents' oral health status, oral health-related behaviors, psychological cognitive factors, self-efficacy, self-perceived oral health and OHRQoL in the short-term (up to 6 months). However, few studies showed the effectiveness of psychological intervention in improving adolescents' oral health status in the long-term (1 to 2 years), including gingivitis and dental caries.

In the present review, the significant short-term improvements in oral health behaviors, self-efficacy and dental plaque level found are consistent with the results of a previous systematic review on the general population. [31] However, in that review, no significant effect of psychological interventions in improving adults' periodontal status, compared with the control, was found. The potential reasons for the contrasting findings may be because the studies included in the previous review mainly recruited dental patients with different levels of periodontal diseases. [52–54] Those recruited dental patients might need clinical periodontal treatment rather than just psychological interventions to improve their periodontal status. The present systematic review findings are also in agreement with a previous systematic review which showed that behavioral interventions could improve adolescents' oral health in the short-term. However, in the previous review, the long-term effects of behavior interventions should be interpreted cautiously due to the limited quality of evidence of the included studies. [16]

The present review fills a research gap in summarizing the effectiveness of psychological interventions in improving oral health in adolescents over the age of 16. [39] Older adolescents usually have worse periodontal conditions. [55] Therefore, there is a need for psychological interventions targeting at this population to improve their oral hygiene behaviors and status. The present review also found significant short-term improvements on the psychological cognitive factors after psychological interventions. However, long-term effectiveness should be interpreted with caution due to limited studies reporting this result. Moreover, the newly added studies in the present review had a good assurance of the fidelity of the intervention process through real-time monitoring and evaluation. [37,39,42] Fidelity refers to the degree to which an intervention is implemented as intended. This ensures the

intervention is delivered consistently and with high quality. [56] In this review, only two studies reporting on dental caries were identified. It is recommended that more studies on the effectiveness of psychological interventions on preventing dental caries should be conducted.

In addition, the present review highlights the importance of having reinforcements in psychological interventions. Among the included studies that conducted long-term follow-ups, five out of the six studies which did not include reinforcement found the clinical outcomes, psychosocial beliefs, and subjective evaluation of oral health status would return to the baseline level in the one-year follow-up. [23,41,43,45,49] In a study which used motivational interviewing as the psychological intervention and had five reinforcements conducted within 6 months, no new caries was found in the two-year follow-up. [37]

The included studies in this review had high heterogeneity in study design, implementation of intervention, follow-up duration and outcome measurements which lowers the certainty of the evidence, the generalizability of the results, and the interpretation of the clinical effects. Firstly, most of the included studies only used a single psychological theory model as the intervention and the model used varied from study to study. As a result, this review cannot identify which psychological theory model is the most useful for designing behavioural interventions for adolescents. Secondly, some of the studies only included a negative control group, which limits the ability to demonstrate the advantages and efficacy of psychological intervention in promoting adolescents' oral health compared to traditional oral health education. Therefore, incorporating both positive and negative control groups would be a more rigorous study design. Thirdly, for some studies, due to imprecise and ambiguous descriptions of the intervention process, it is difficult to accurately determine the duration of the intervention and whether they closely followed the stated psychological theory or model in the implementation of intervention.

The present review also has other limitations such as only studies with quantitative outcome measures were included. Qualitative studies can have in-depth investigation on subjective oral health outcomes, including the individual's oral health function and well-being. [57] Since psychological factors help to explain the impact of oral health on personal well-being, collecting subjective information can lead to better understanding of the psychological intervention in improving the oral health of adolescents from a personal subjective perspective. [23] It is noteworthy that the studies in this review were limited to four countries or areas, which may affect external validity. Thus, well-designed randomized control trials need to be conducted in other regions to verify the generalizability of the effectiveness of psychological interventions in enhancing adolescents' oral health in different cultural and socio-economic contexts. Besides, more studies with extended observation periods are necessary for a proper evaluation of the long-term impact of psychological interventions on adolescents' oral health and other outcomes. Furthermore, future research should measure the human resources and time cost for conducting the psychological intervention so that cost-effectiveness analysis can be conducted. Finally, more multivariable modeling strategies and also qualitative studies are necessary to identify the mechanisms of psychological interventions in modifying oral health behaviors and status among adolescents. Investigating these factors can help develop more effective interventions tailored to adolescents and optimize their impact.

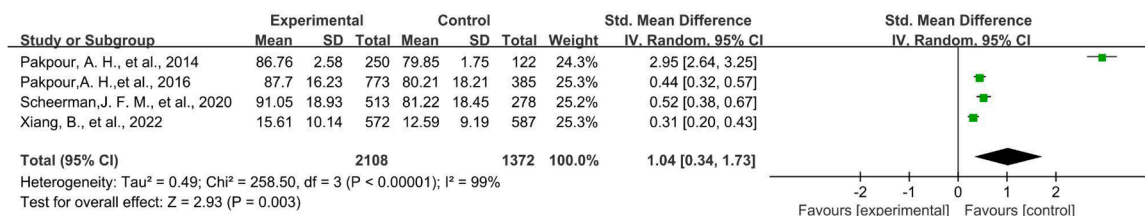


Fig. 6. Forest plot for the short-term psychological intervention's effectiveness on OHRQoL.

6. Conclusion

In conclusion, the present systematic review found low to moderate evidence showing that psychological interventions are effective in improving adolescents' oral hygiene and periodontal status when compared with traditional oral health education or negative control. By targeting attitudes, beliefs, self-efficacy, and motivation, psychological interventions can promote good oral hygiene practices, improving oral health status and OHRQoL among adolescents in the short-term. Further research is needed to explore the long-term effectiveness and sustainability of psychological interventions.

CRedit authorship contribution statement

Isabella L. He: Writing – original draft, Formal analysis, Data curation, Conceptualization. **Pei Liu:** Writing – review & editing, Supervision, Conceptualization. **May C.M. Wong:** Writing – review & editing, Methodology. **Chun Hung Chu:** Writing – review & editing, Supervision. **Edward C.M. Lo:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of competing interest

No potential conflicts of interest concerning the authorship and/or publication of this article are disclosed by the authors.

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Supplementary materials

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