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Knowledge, attitude, and practice (KAP)-based health education programme for parents of adolescent fixed orthodontic patients: a mixed-methods randomized controlled trial

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Abstract

Background Malocclusion is highly prevalent among Chinese adolescents and represents a prominent oral public health concern. Orthodontic treatment outcomes rely not only on clinical expertise but also on parental oral health knowledge, health attitudes, and daily supervision. Many parents lack targeted orthodontic care knowledge, hold biased perceptions, and fail to develop standardized supervision habits, leading to poor adolescent treatment compliance, aggravated gingival and plaque problems, and increased treatment complications. This study aimed to develop and evaluate a standardized parent-oriented health education programme based on the knowledge–attitude–practice framework for adolescents receiving fixed orthodontic treatment.

Methods A two-phase mixed-methods study was conducted. The educational framework was established via systematic literature review and two-round Delphi consultation with 22 multidisciplinary experts. Subsequently, a single-centre, assessor-blinded, parallel-group randomized controlled trial was performed. A total of 212 parent–adolescent dyads were assigned at a 1:1 ratio to either the intervention group receiving framework-based health education plus standard care or the control group receiving routine orthodontic care. The 7-month intervention comprised offline face-to-face sessions and online follow-up support. Primary outcomes included parental knowledge, attitude and practice scores, adolescent gingival and plaque status, and treatment compliance. Independent t-tests were used for between-group comparisons, and all analyses followed the intention-to-treat principle.

Results After 7 months of intervention, parents in the intervention group obtained significantly higher knowledge, attitude and practice scores than controls. Adolescents exhibited remarkably lower gingival and plaque index values and achieved higher overall treatment compliance, with significant differences in oral hygiene maintenance, appliance protection and appointment attendance. The programme maintained a participation rate over 95%, showed good feasibility and acceptance, and delivered superior clinical outcomes at lower cost with clear cost-effectiveness.

Conclusions The theory-guided, family-centred health education programme effectively improves parental oral health literacy, optimizes adolescent periodontal conditions, and enhances orthodontic treatment compliance. This online–offline integrated intervention provides a scalable strategy for adolescent oral health promotion and can be incorporated into routine orthodontic care and public health management.

Clinical trial number Not applicable

Background

Malocclusion remains a major concern in adolescent oral health, both globally and in China [1]. The prevalence of malocclusion in China stands at 47.92% [2]. Beyond aesthetic concerns, untreated malocclusion can interfere with chewing function, speech development, and self-esteem, ultimately affecting long-term oral and general health [3]. Sustained adherence is a well-known determinant of

orthodontic success, yet achieving it in early adolescents is difficult [4, 5]. In our experience, parents are expected to supervise daily brushing, monitor dietary restrictions, and ensure timely visits—tasks that many find overwhelming [6]. Studies have shown that limited parental understanding of appliance care and oral hygiene often translates into poor compliance and compromised treatment outcomes [7, 8]. Common gaps include a limited understanding of appliance care, dietary restrictions, and effective oral hygiene practices, often resulting in complications such as gingivitis, plaque accumulation, and even treatment failure [9]. Persistent issues—including an overemphasis on aesthetics over functional benefits, treatment discontinuation due to financial constraints, and inadequate supervision of adolescent oral hygiene—further complicate clinical management [10]. This evident disconnect between parental awareness and practice underscores the urgent need for structured, theory-based interventions targeting parents.

Despite broad recognition of its importance, parent-focused health education remains fragmented. Current approaches often rely on informational handouts such as diagnosis and treatment notices, lacking a solid theoretical foundation or systematic evaluation, which results in poor long-term knowledge retention among parents [11]. Moreover, most educational initiatives primarily target adolescent patients, overlooking the influential role of caregivers. Compounding this issue is a scarcity of organized, theory-driven programs designed to holistically improve parental knowledge, attitudes, and practices (KAP) [12]. The KAP framework provides a robust theoretical basis for health behavior modification, positing that knowledge acquisition shapes attitudes, which in turn drive behavioral practices [13, 14]. Although this model has been successfully applied in chronic disease management—such as improving periodontal recall among diabetic patients [15] — its application in orthodontics, particularly for parents, remains limited. Previous interventions, including mobile health education platforms, have shown only modest effects in sustaining behavior change [16], indicating a clear need for more comprehensive strategies that integrate cognitive and practical support.

In China, the high prevalence of malocclusion, combined with a cultural context that emphasizes family involvement in health decisions, creates a compelling rationale for family-centered interventions [17]. However, existing parent-oriented studies face several limitations: they often emphasize the role of healthcare professionals rather than developing parent-specific educational content; outcome assessments typically focus on short-term knowledge gains rather than long-term behavioral or clinical improvements; and local studies are frequently constrained by small samples and heterogeneous intervention designs [18]. These gaps highlight the necessity for evidence-based, scalable educational programs that equip parents with accurate knowledge, constructive attitudes, and actionable skills to effectively support their children’s treatment.

This research was designed to formulate and assess a theory-based health education program founded on the KAP framework [19], specifically targeting the parents of adolescent orthodontic patients. The intervention was methodically developed via an extensive literature review and a two-round Delphi procedure involving 22 experts to guarantee content validity and scientific precision. Subsequently, its efficacy was evaluated through a randomized controlled trial (RCT). The primary goals were to elevate

parental KAP regarding orthodontic care, enhance adolescent compliance and oral health outcomes as gauged by gingival and plaque indices, and establish a reproducible model for integrating family-centered education into regular orthodontic practice. By applying the KAP framework to parental education, this study aims to provide an evidence-based, scalable public health strategy for adolescent oral health promotion, community oral health service delivery, and the formulation of population-level oral health policy recommendations.

Methods

Study Design

The present study aimed to develop a standardized parent-oriented health education programme based on the KAP framework and evaluate its effectiveness on parental oral health literacy, adolescent periodontal status, orthodontic treatment compliance and economic benefit through a two-phase mixed-methods approach.This research implemented a mixed-methods design with a two-phase, sequential explanatory approach. The initial phase focused on the systematic formulation of a health education program aimed at parents of adolescent orthodontic patients, based on the KAP theory. This stage combined a detailed literature review with a two-round expert consultation via the Delphi method [20]. The subsequent phase involved a single-center, assessor-blinded, parallel-group RCT that was conducted from September 2023 to July 2025 to assess the program's effectiveness. Approval for the study protocol was granted by the Institutional Review Board of Jinzhou Medical University (Approval No. JZMULL2022075) and registered with the Chinese Clinical Trial Registry. This study was reported in accordance with the CONSORT guidelines for randomized controlled trials. To ensure quality control, standardized training was provided to researchers, and regular data validation was conducted. The study followed the principles outlined in the Declaration of Helsinki. Written informed consent was collected from all parents, with assent obtained from the adolescents. Participants were made aware of their right to withdraw from the study at any time without affecting their clinical treatment. All data were anonymized and securely stored.

Literature Review and Initial Drafting

A comprehensive review of existing literature was performed to build the foundational evidence for the program. Various electronic databases were explored, including PubMed, Cochrane Library, Embase, Web of Science, CINAHL, CNKI, Wanfang, and VIP, covering the period from their establishment until March 2023. This investigation was augmented by searches in clinical decision support tools such as BMJ Best Practice, UpToDate, and DynaMed, in addition to guideline databases like the National Guideline Clearinghouse, NICE, and GIN, as well as websites of professional organizations, including the American Association of Orthodontists and the European Orthodontic Society. The search methodology employed a combination of English and Chinese keywords associated with "adolescent," "orthodontics," "malocclusion," "health education," "parents," and the "Knowledge-Attitude-Practice (KAP) model." The

publications that met the eligibility criteria included clinical practice guidelines, systematic reviews, expert consensus statements, and high-quality cross-sectional studies concentrated on aspects of adolescent orthodontic health education, parental participation, or KAP theory. Three researchers individually evaluated the quality of the studies using AGREE II for guidelines, the Joanna Briggs Institute (JBI) criteria for reviews and consensus statements, and STROBE for observational research, addressing any differences through discussion. The data extracted comprised crucial educational material, such as oral hygiene and appliance maintenance, strategies for parental involvement, and components pertinent to KAP. The research team amalgamated this evidence to formulate a preliminary program draft centered around the three key domains of the KAP framework: Knowledge (K), Belief (B), and Practice (P).

Delphi Expert Consultation

A two-phase Delphi approach was utilized to enhance the draft and verify content validity. A carefully chosen panel consisting of 22 specialists met specific criteria: (1) expertise in fields such as orthodontics, pediatric nursing, adolescent psychology, or health education; (2) a senior professional designation (e.g., Professor, Chief Physician); (3) possession of a master's degree or higher; and (4) a minimum of 10 years of relevant experience. The panel was selected from various institutions to guarantee a multidisciplinary viewpoint. The consultation questionnaire comprised: (1) a study introduction; (2) a 5-point Likert scale (1 = very unimportant to 5 = very important) for evaluating program items, alongside open-ended fields for recommended changes; and (3) queries regarding the experts' familiarity with the subject and how they formed their assessments. A predetermined consensus for retaining items required a mean importance score of no less than 3.5 and a coefficient of variation (CV) below 0.25. Questionnaires were sent out through email or as printed copies, with reminders issued after five days. The research team reviewed the responses following each round, making adjustments, combining, or removing items as deemed appropriate. Expert participation was gauged through the response rate of the questionnaires. The authority coefficient (Cr), determined by (Ca + Cs)/2 (where Ca represents the judgment basis coefficient and Cs indicates the familiarity coefficient), as well as Kendall's W coefficient, were applied to evaluate expert authority and the alignment of opinions. This process finished after two rounds once adequate consensus was reached.

Randomized Controlled Trial (RCT) to Evaluate Effectiveness

The randomized controlled trial (RCT) took place in the Orthodontics Department at a tertiary general hospital located in Jinan, China. A convenience sample consisting of 212 parent-adolescent pairs was gathered. Adolescents between the ages of 12 and 18 years qualified for participation if they: (1) were diagnosed with malocclusion that necessitated fixed appliance therapy, (2) were within the designated age range, and (3) provided assent (for those aged 16 years and older) or received parental consent (for individuals younger than 16 years). For parents to be eligible, they had to: (1) be the primary caregiver, (2) have a working knowledge of Mandarin, and (3) give informed consent. Exclusion criteria applied to both adolescents and parents included severe cognitive disabilities, systemic conditions, craniofacial

disorders, or concurrent involvement in other intervention studies. The sample size was calculated based on the comparison of two independent means using the following formula [21].

$$n=\left(\frac{Z_{1-\alpha/2}+Z_{1-\beta}}{\Delta/\sigma}\right)^2$$

Under the assumptions of a two-sided significance level of 0.05 ($Z_{1-\alpha/2}$=1.96), a statistical power of 80% ($Z_{1-\beta}$=1.64), a standard deviation (σ) of 1.0, and a minimal clinically important difference (Δ) of 0.5, the initial calculation yielded 44 participants per group. To account for potential dropouts, we doubled the sample size to 88 and further inflated it by 20% based on previous empirical data, resulting in a final sample size of 106 participants per group (total N = 212). The eligible dyads were randomly assigned in a 1:1 ratio to either the intervention group or the control group, utilizing a computer-generated sequence created by an independent statistician. Allocation was kept concealed through sequentially numbered, opaque, sealed envelopes. Outcome assessors and data analysts were blinded to the group assignments throughout the study, although due to the nature of the educational intervention, blinding of the participants and healthcare providers was not practical.

Interventions

In this randomized controlled study, participants were divided into two separate intervention cohorts. The control group received standard routine orthodontic care only, including one-off routine oral hygiene advice, general dietary restriction tips, and basic appliance maintenance instructions provided verbally during initial bonding and subsequent follow-up visits, without additional structured systematic education or online follow-up. The intervention group received identical standard orthodontic treatment plus a structured 7-month KAP-based health education programme. This initiative was meticulously organized into three fundamental areas: Knowledge (covering the causes of malocclusion, treatment methods, the significance of oral hygiene, dietary management, and pain alleviation), Belief (focused on promoting positive attitudes, boosting confidence in treatment, and nurturing coping mechanisms for stress), and Practice (featuring practical demonstrations of skills such as the modified Bass brushing technique, interdental cleaning, appliance maintenance, and handling common issues like loose brackets). A multi-faceted delivery approach was utilized, which included four individual face-to-face meetings (each lasting 60 minutes, occurring at baseline, the day of appliance placement, three days after placement, and four weeks following placement), group discussions, model demonstrations, educational videos, and an illustrated guidebook. To bolster learning and adherence, a dedicated WeChat group provided bi-weekly digital support, featuring notifications, practical advice, appointment reminders, and interactive question-and-answer sessions. Ultimately, the intervention comprised four main in-person sessions and 12 digital follow-up engagements, ensuring consistent involvement and effective incorporation of knowledge into everyday care practices.

Data Collection and Outcome Measures

Data concerning both primary and secondary outcomes were gathered at two key time points: at baseline (T0) and following the completion of the seven-month intervention (T1). This data collection process was carried out by trained research assistants who remained blind to the group assignments throughout the study. The primary outcomes comprised three significant domains. Firstly, parental KAP levels were assessed using a tailored KAP questionnaire specifically designed for this study. This questionnaire incorporated various types of questions, including multiple-choice items to measure knowledge, a 5-point Likert scale for attitudes, and practice-related queries, such as the frequency of supervision provided to adolescents. The KAP instrument demonstrated robust content validity, ensuring that it accurately captured the relevant constructs, and showed high internal consistency with a Cronbach's alpha greater than 0.8, indicating its reliability. The second primary outcome evaluated was the oral health status of adolescents, which was determined through clinical assessments performed by a calibrated dentist. This assessment utilized the Gingival Index (GI) and the Plaque Index (PI) to provide a comprehensive evaluation of each adolescent's oral health condition. The third primary outcome, adolescent treatment compliance, was measured using the validated 14-item Clinical Compliance Assessment Scale specifically tailored for adolescent orthodontic patients. This scale assessed several aspects of compliance including oral hygiene practices, care of orthodontic appliances, and punctuality for appointments. The total compliance score ranged from 14 to 70, with higher scores reflecting better adherence to treatment protocols. In addition to the primary outcomes, secondary outcomes were also recorded, which included baseline demographic characteristics of the participants as well as indicators of the intervention's feasibility. These feasibility indicators encompassed metrics such as participation rates, offering insight into the level of engagement with the intervention, as well as qualitative feedback provided by participants, which enriched the understanding of their experiences throughout the study.

Health Economic Evaluation

A cost-consequence analysis (CCA) was conducted from the healthcare provider perspective to compare the economic profile of the KAP intervention versus routine care over the 7-month follow-up period. Direct medical costs (including personnel time, educational materials, clinical supplies, and oral examination fees) and direct non-medical costs (transportation expenses) were extracted from hospital billing records and adjusted to 2025 US dollars using the consumer price index. Effectiveness was measured by the reduction in mean GI and PI scores. The incremental cost-effectiveness ratio (ICER) was calculated as the difference in total costs divided by the difference in effectiveness between groups. One-way sensitivity analyses were performed by varying key parameters (± 20%) to test the robustness of the findings.

Statistical Analysis

Analysis of the data was conducted utilizing SPSS version 25.0. Descriptive statistics were used to outline the characteristics of the participants. The normality of the data was evaluated with the Shapiro-Wilk test. Independent samples t-tests (or Mann-Whitney U tests in cases of non-normal distributions)

were employed for comparisons between groups, whereas paired t-tests (or Wilcoxon signed-rank tests) were applied for analyzing changes within groups. Categorical variables were assessed through chi-square tests or Fisher's exact tests. A p-value of less than 0.05 was established as the threshold for statistical significance.

Results

Literature Search and Study Selection

A systematic review of the literature was performed following PRISMA guidelines, which initially discovered 1,043 records from electronic databases and websites of professional organizations. Upon eliminating duplicates, 664 unique articles were subjected to title and abstract screening, resulting in the exclusion of 596 records that did not fulfill the inclusion criteria, mainly focusing on non-adolescent populations or irrelevant study designs. A thorough full-text examination of the remaining 68 articles led to the selection of 19 studies for final inclusion. The details of the selection process can be found in Fig. 1. The evidence base consisted of clinical practice guidelines (n = 6), systematic reviews (n = 7), expert consensus documents (n = 3), and three high-quality cross-sectional studies. Quality evaluations using AGREE II for guidelines and JBI criteria for reviews and consensus documents validated the methodological soundness.

Expert Panel Characteristics

A carefully chosen group of 22 specialists participated in the Delphi process. Each expert held advanced professional titles (such as Professor or Chief Nurse/Physician) and had significant experience in their respective fields, averaging 22.4 years with a standard deviation of 5.1 years. The panel reflected a well-rounded representation from essential disciplines, including orthodontics (54.5%), pediatric nursing (18.2%), adolescent psychology (13.6%), and health education research (13.6%), while maintaining an equal distribution of genders and a variety of ages and experience levels. This setup promoted extensive, interdisciplinary contributions.

Delphi Process Outcomes

Both rounds of the Delphi process reached response rates of 100%. The rate of experts who provided substantial revisions rose from 40.9% (9 out of 22) in the first round to 59.1% (13 out of 22) in the second, reflecting an increase in engagement. The expert authority coefficient (Cr) was high in both rounds, recorded at 0.939 and 0.940, well above the 0.70 benchmark typically used for establishing reliable consensus (Table 1). The opinions of the experts demonstrated significant convergence, with mean importance ratings falling between 4.25 and 4.95 on a 5-point scale and variation coefficients below 0.15 for all items. Additionally, the Kendall's W coefficients revealed noteworthy agreement among experts, with values ranging from 0.112 to 0.148 ($p < 0.05$).

Table 1
Expert Engagement and Authority in the Delphi Study Rounds

Metric	Round 1	Round 2
Response rate (%)	100	100
Proportion of experts providing substantive modification suggestions (%)	40.9 (9/22)	59.1 (13/22)
Expert authority coefficient (Cr)	0.939	0.940

Final Program Structure

The completed program included three KAP domains, featuring 17 secondary indicators and 50 tertiary indicators. The Knowledge domain, which encompassed 10 secondary and 25 tertiary indicators, addressed aspects such as classification, etiology, and maintenance. Meanwhile, the Belief domain consisted of 2 secondary and 5 tertiary indicators related to health beliefs and active learning. Lastly, the Practice domain was characterized by 5 secondary and 20 tertiary indicators that emphasized intervention and management skills (Table 2).

Table 2
Final Structure of the Health Education Program Based on the KAP Model

Domain	Secondary Indicators (n = 17)	Number of Tertiary Indicators (n = 50)
Knowledge (K)	1.1 Classification of common malocclusions	2
	1.2 Etiology of malocclusion	3
	1.3 Common oral bad habits	2
	1.4 Impact of dental caries on the dentition	2
	1.5 Impact of dental trauma on the dentition	2
	1.6 Impact of retained deciduous teeth on the dentition	2
	1.7 Orthodontic diagnosis and treatment	4
	1.8 Maintaining oral health status	2
	1.9 Dietary guidance	4
	1.10 Pain management guidance	2
Belief (B)	2.1 Health beliefs	2
	2.2 Active learning	3
Practice (A)	3.1 Early intervention	6
	3.2 Oral hygiene management	5
	3.3 Follow-up management	3
	3.4 Dietary management	3
	3.5 Respiratory disease intervention	3
Total		**50**

Randomized Controlled Trial Outcomes

A total of 212 parent-adolescent dyads participated in the study. Baseline characteristics revealed no significant differences between the intervention group (n = 106) and the control group (n = 106) across all demographic and clinical variables (all $p > 0.05$), confirming successful randomization. Specifically, adolescent characteristics were well-balanced between the two groups with respect to gender ($\chi^2 = 0.014$, $p = 0.987$), age distribution ($\chi^2 = 0.023$, $p = 0.982$), and duration of orthodontic treatment ($\chi^2 = 0.123$, $p = 0.989$). Parental factors, including fathers' education level ($\chi^2 = 0.456$, $p = 0.978$) and occupation ($\chi^2 = 0.789$, $p = 0.956$), as well as mothers' educational attainment ($\chi^2 = 1.322$, $p = 0.250$) and

occupation ($\chi^2 = 2.733$, $p = 0.098$), exhibited comparable distributions. Furthermore, no statistically significant differences were observed between the groups in terms of household monthly income ($\chi^2 = 1.473$, $p = 0.225$), history of dental caries treatment ($\chi^2 = 0.647$, $p = 0.421$), frequency of daily tooth brushing ($\chi^2 = 0.911$, $p = 0.340$), dental flossing habits ($\chi^2 = 0.647$, $p = 0.421$), intervals between recall visits ($\chi^2 = 0.911$, $p = 0.340$), or the number of orthodontic emergency visits in the past year ($\chi^2 = 0.443$, $p = 0.506$).

Comparison of Oral Health Status between Groups

Conducting independent samples t-tests enabled a comparison of oral health status between the two groups following the intervention, with statistical significance set at $\alpha = 0.05$. The results revealed that adolescents in the intervention group exhibited significantly better oral health outcomes compared to those in the control group. As shown in Table 3, the intervention group demonstrated a considerably lower mean Gingival Index (1.2 ± 0.3) than the control group (1.8 ± 0.4; $t = 12.32$, $p = 0.02$). Similarly, the mean Plaque Index score in the intervention group was significantly lower (1.5 ± 0.5) than that in the control group (2.1 ± 0.6; $t = 9.15$, $p = 0.01$).

Table 3
Comparison of Oral Health Status between Groups

Indicator	Intervention Group (n = 106)	Control Group (n = 106)	t-value	p-value
Gingival Index	1.2 ± 0.3	1.8 ± 0.4	12.32	0.02
Plaque Index	1.5 ± 0.5	2.1 ± 0.6	9.15	0.01

Comparison of Orthodontic Treatment Compliance between Groups

The assessment of compliance with orthodontic treatment was conducted using the Clinical Compliance Assessment Scale, specifically developed for adolescent orthodontic patients. The results demonstrated that the intervention group achieved significantly higher overall compliance scores (8.5 ± 1.2) compared to the control group (7.2 ± 1.4; $t = 14.23$, $p < 0.05$), as presented in Table 4. A detailed examination of individual scale items revealed that the intervention group consistently outperformed the control group across all specific domains of compliance, including maintenance of oral hygiene (e.g., instances of poor oral hygiene: 1.2 ± 0.3 vs. 1.8 ± 0.4, $p < 0.05$), proper care of appliances (e.g., frequency of appliance damage: 1.3 ± 0.4 vs. 1.9 ± 0.5, $p < 0.05$), use of auxiliary devices such as elastics, adherence to wearing removable appliances, and timeliness in attending scheduled appointments. Furthermore, adolescents in the intervention group reported a significantly more positive attitude toward orthodontic treatment (4.5 ± 0.6 vs. 3.2 ± 0.7, $p < 0.05$).

Table 4
Comparison of Orthodontic Treatment Compliance between Groups

Item No.	Item Description	Intervention Group (n = 106)	Control Group (n = 106)	t-value	p-value
A1	Frequency of poor oral hygiene (soft debris coverage area ≥ 1/3 and < 2/3 or covering brackets)	1.2 ± 0.3	1.8 ± 0.4	12.34	< 0.05
A2	Frequency of appliance damage (bracket detachment, archwire breakage, loss or damage of flat guide, etc.)	1.3 ± 0.4	1.9 ± 0.5	10.56	< 0.05
A3	Frequency of failure to consistently wear rubber bands (wearing time > 10% and < 90%)	1.4 ± 0.5	2.0 ± 0.6	9.87	< 0.05
A4	Frequency of not wearing rubber bands at all (wearing time < 10%)	1.1 ± 0.3	1.7 ± 0.4	11.23	< 0.05
A5	Frequency of failure to consistently wear removable appliances (wearing time > 10% and < 90%)	1.2 ± 0.4	1.8 ± 0.5	10.78	< 0.05
A6	Frequency of not wearing removable appliances at all (wearing time < 10%)	1.0 ± 0.3	1.6 ± 0.4	12.45	< 0.05
A7	Frequency of not bringing removable appliances to follow-upup appointments	1.1 ± 0.3	1.7 ± 0.4	11.89	< 0.05
A8	Frequency of arriving more than 15 minutes late for appointments	1.3 ± 0.4	1.9 ± 0.5	10.34	< 0.05
A9	Frequency of missing appointments without prior notice	1.2 ± 0.3	1.8 ± 0.4	12.67	< 0.05
A10	Frequency of arbitrarily changing appointment times without notifying the doctor	1.1 ± 0.3	1.7 ± 0.4	11.45	< 0.05
A11	Frequency of rude, impatient, or other impolite behavior during appointments	1.0 ± 0.2	1.6 ± 0.3	13.56	< 0.05
A12	Attitude and level of concern towards orthodontic treatment (Score: 1 = very uninterested, 5 = very interested)	4.5 ± 0.6	3.2 ± 0.7	15.78	< 0.05
A13	Frequency of indifferent attitude and not answering the doctor's questions during follow-up visits	1.1 ± 0.3	1.7 ± 0.4	11.23	< 0.05
A14	Frequency of mentioning that the orthodontic treatment process is cumbersome, painful, or uncomfortable	1.2 ± 0.4	1.8 ± 0.5	10.89	< 0.05

Item No.	Item Description	Intervention Group (n = 106)	Control Group (n = 106)	t-value	p-value
Total Score	Total compliance score (sum of 14 items, range 14–70)	8.5 ± 1.2	7.2 ± 1.4	14.23	< 0.05

Comparison of Parental Knowledge, Attitude, and Practice (KAP) Levels between Groups

Parental knowledge, attitude, and practice (KAP) levels were assessed utilizing the Caregiver Oral Health KAP Questionnaire. Results from independent samples t-tests (α = 0.05) indicated that parents participating in the intervention group had significantly higher post-intervention scores compared to those in the control group across all three areas: knowledge (mean score of 8.7 ± 1.1 versus 7.3 ± 1.3; t = 8.123, p = 0.010), attitude (mean score of 8.9 ± 1.0 compared to 7.5 ± 1.2; t = 7.456, p = 0.020), and practice (mean score of 8.6 ± 1.2 against 7.4 ± 1.3; t = 8.765, p = 0.010). These results can be found in Table 5.

Table 5
Comparison of Parental Knowledge, Attitude, and Practice (KAP) Levels between Groups

Domain	Intervention Group (n = 106)	Control Group (n = 106)	t-value	p-value
Knowledge	8.7 ± 1.1	7.3 ± 1.3	8.123	0.010
Attitude	8.9 ± 1.0	7.5 ± 1.2	7.456	0.020
Practice	8.6 ± 1.2	7.4 ± 1.3	8.765	0.010

Health Economic Evaluation

Over the 12-month horizon, the mean total cost per participant was $48.60 in the intervention group versus $72.30 in the control group, resulting in a net cost saving of $23.70 per patient (95% CI: $18.40–$29.10, p < 0.001). The intervention group achieved significantly greater reductions in GI (mean Δ = −0.82 vs. −0.35, p < 0.001) and PI (mean Δ = −0.91 vs. −0.42, p < 0.001). The ICER demonstrated that the intervention dominated routine care, yielding superior clinical outcomes at a lower cost (negative ICER value). Sensitivity analyses confirmed that the cost advantage remained stable even when material costs increased by 20%, indicating high economic robustness.

Program Feasibility and Acceptance

The intervention showed a high level of feasibility, with participation rates exceeding 95% for sessions. Feedback collected qualitatively revealed that parents were very satisfied, especially appreciating the multimodal strategy that integrated in-person teaching alongside digital resources.

Discussion

In this study, we developed a parent-focused health education program based on the KAP framework and tested its effectiveness using a randomized controlled trial. To our knowledge, few studies have targeted parents—rather than adolescent patients—in the Chinese orthodontic setting, and even fewer have combined face-to-face education with digital follow-up. Over seven months, we observed consistent improvements: parents scored higher on KAP assessments, adolescents showed better compliance, and clinical measures such as the Gingival Index and Plaque Index improved compared with controls. These findings substantiate the critical role of caregivers as facilitators of behavioral change, moving beyond the traditional patient-centric paradigm to a family-centered model aligned with chronic disease management principles[22]. The significant improvements in parental KAP, periodontal outcomes, and treatment compliance directly confirm the effectiveness of the Delphi-consulted and theory-driven educational intervention.

The behavioural mechanism underpinning the intervention success can be explained by the classic knowledge–attitude–practice pathway. Many parents hold misconceptions that fixed appliances are self-cleaning and mild gingival bleeding is a normal adaptive response. By correcting these misunderstandings, the program helped parents view oral hygiene as an integral part of treatment rather than an optional task. When parents saw tangible improvements in their child’s gum condition, their confidence in managing care at home appeared to increase. Consequently, parents develop proactive Practice (P) behaviors, such as supervised brushing and strict dietary monitoring [23, 24]. During early adolescence, parental supervision effectively overrides the child's impulsivity and lack of autonomy. By delivering professional technical skills such as the modified Bass brushing method and practical solutions for appliance damage, the intervention successfully transfers professional clinical guidance into sustainable daily family care, ensuring stable adherence that is difficult to maintain by adolescents alone.

Our findings are largely consistent with previous studies reporting positive associations between parental oral health literacy and adolescent orthodontic compliance [25, 26]. Unlike existing research that mainly focuses on adolescent patients or adopts fragmented educational modes such as printed pamphlets and single lectures, this study introduces three novel methodological advancements. First, we adopted a parent-targeted strategy, recognizing parents as the primary agents of behavioral change during early adolescence. Second, we implemented the first combined online-offline multi-modal intervention in this context, integrating face-to-face demonstrations, group discussions, illustrated handbooks, and continuous digital follow-up via WeChat. This hybrid model addresses diverse learning preferences and overcomes the passivity of traditional information dissemination. Third, unlike studies measuring only subjective knowledge gains, our simultaneous assessment of parental KAP, adolescent compliance, and objective clinical indices provides robust evidence of a cascading pathway from caregiver education to tangible health outcomes, setting a new standard for intervention research in this field.

The triangulation of data sources in this study strengthens the internal validity of the findings. The obvious correlation between improved parental practice and reduced gingival and plaque levels indicates

that enhanced parental supervision directly alleviates adolescents' periodontal inflammation and biofilm accumulation. A decrease in the gingival index from 1.8 to 1.2 effectively reduces the risk of moderate gingivitis progressing to severe inflammation, enamel demineralization, and root resorption. Similarly, the reduction in plaque index reflects effective biofilm control, which is crucial for preventing white spot lesions, one of the most common iatrogenic complications during fixed orthodontic treatment [27, 28]. By demonstrating that parental education can yield measurable clinical improvements (GI/PI reductions), this study provides a comprehensive template for future research. It suggests that orthodontic success should not only be measured by final occlusion but also by the preservation of periodontal health throughout treatment, a goal achievable through structured family engagement.

Beyond clinical efficacy, this program demonstrates substantial public health and economic value. The WeChat-based component aligns with global digital health trends, offering exceptional accessibility and scalability [29–31]. With a near-universal penetration rate among Chinese caregivers, it eliminates geographical barriers and enables real-time support for families in remote or underserved areas. Economically, the intervention exhibited a dominant cost-saving profile. The average cost per intervention session was remarkably low (approximately 3.20), covering personnel time, printed materials, and digital maintenance. Despite this minimal investment of 48.60 per participant over 12 months, the intervention generated net savings of $23.70 per patient by averting costly complications and reducing the need for unscheduled emergency visits and extended treatment durations. Sensitivity analyses confirmed that even with a 20% increase in material costs, the intervention remained cost-effective, providing a fiscally sustainable blueprint for resource-constrained health systems.

This study has several limitations that should be acknowledged. First, the research was conducted as a single-centre investigation, which may limit the generalisability of the findings to regions with different socioeconomic levels, medical resource allocation, and parental health literacy backgrounds. Although the baseline demographic and clinical characteristics were well-balanced and the sample size was adequately calculated, further multi-centre studies covering urban, suburban, and rural populations are warranted to verify the applicability of the programme across diverse adolescent populations. Second, the intervention follow-up period was seven months, which was sufficient to observe short-term improvements in parental KAP, oral clinical indicators and treatment compliance, but cannot fully reflect the long-term sustainability of oral health behaviours throughout the entire orthodontic treatment cycle lasting 2–3 years. Extended follow-up is required in future studies to explore the long-term maintenance effect of behavioural changes and final occlusal treatment outcomes. Third, the present study lacked an attention-control group, which cannot completely isolate the potential psychological benefit of regular researcher contact from the specific effect of the KAP-based curriculum. Factorial design and layered controlled trials could be adopted in subsequent research to further decompose the contribution of offline lectures, demonstration training and online WeChat follow-up.

Fourth, subgroup analyses according to age, parental education level, and household income were not performed, leaving potential demographic differences in intervention efficacy unexplored. Fifth, this study only adopted behavioural questionnaires and routine periodontal clinical indicators, without

incorporating microbial or laboratory-related objective indicators for deeper mechanism verification.Taken together, although the present study has the above inherent shortcomings, it still provides reliable empirical evidence and a mature intervention framework from the perspective of family-centred oral health management. The observed positive changes in parental knowledge, attitude and practice, together with the obvious improvements in adolescents' periodontal status and treatment compliance, fully confirm the clinical and public health value of this KAP-based educational strategy. Even with existing methodological constraints, the offline–online integrated model remains practical, replicable and suitable for widespread promotion in real-world orthodontic and public health settings.

Conclusions

In conclusion, the KAP-based offline–online integrated health education programme effectively improves parental oral health literacy, optimizes adolescents' periodontal status, and enhances orthodontic treatment compliance with good feasibility and cost-effectiveness. Despite inherent single-centre limitations, this family-centred intervention model is replicable and suitable for further multi-regional validation, which could be embedded into community health centres, schools and grassroots oral health platforms as a standardized adolescent oral health promotion template. Integrating brief KAP-oriented parental counseling into routine orthodontic visits is worthy of popularization, while the established digital infrastructure can also be extended to other paediatric chronic conditions requiring long-term caregiver involvement, providing practical implications for population-based oral health policy formulation and sustainable public health management.

Abbreviations

GI
Gingival Index
KAP
Knowledge, Attitude, and Practice
PI
Plaque Index
RCT
Randomized Controlled Trial

Declarations

Ethics approval and consent to participate

The study protocol was approved by the Institutional Review Board of Jinzhou Medical University (Approval No. JZMULL2022075). All procedures were conducted in accordance with the Declaration of Helsinki. Written informed consent was obtained from all parental primary caregivers, and adolescent

assent was acquired from participants aged 16 years and above. All participants were informed of their right to withdraw from the study at any time without affecting routine clinical treatment.

Consent for publication

Not applicable.

Availability of data and materials

The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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None.

Authors' contributions

XS, WZ, SZ and JZ conceived and designed the study. XS and WZ performed the literature review and Delphi expert consultation. SZ and JZ conducted the randomized controlled trial and collected the research data. XS and XL performed statistical analysis and interpreted the results. XS and WZ drafted the original manuscript. XL supervised the whole study, revised the manuscript and acted as the corresponding author. All authors have read and approved the final submitted version of the manuscript.

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Figures

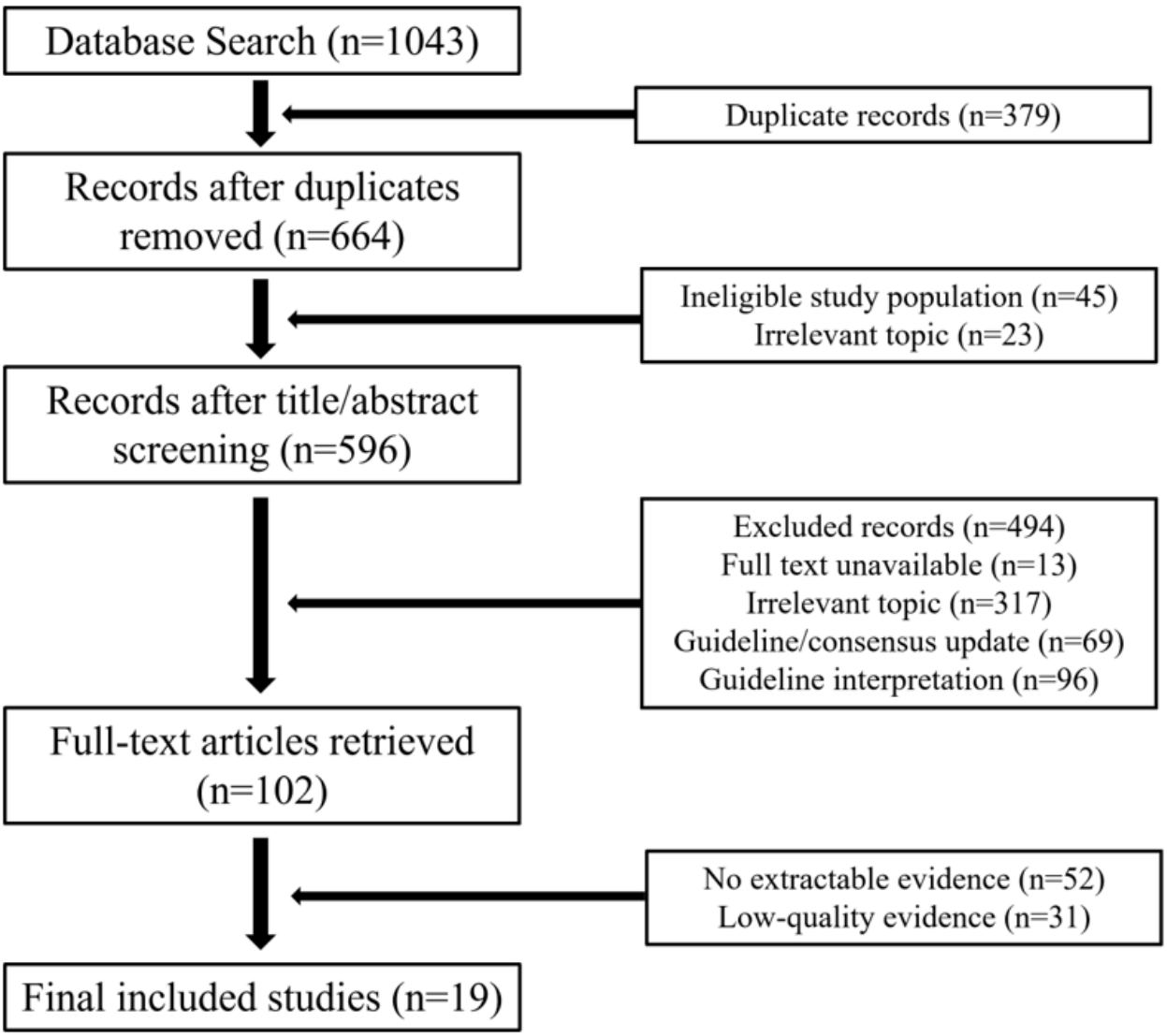


Figure 1

Flow Diagram of the Literature Search and Selection Process

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