Integrating team-based and peer-teaching strategies for standardized dental residency: a path to active learning and professional growth

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Abstract

Background This study aimed to assess the effectiveness of an integrated Team-Based Learning (TBL) and Peer Teaching (PT) model in enhancing theoretical knowledge, clinical competencies, and engagement among dental residents, offering insights for improving stomatology education.

Methods This study was conducted at the affiliated stomatology hospital of Guangzhou medical university between 2021 and 2023. The 2021–22 cohort ($n = 39$) students received a traditional teacher-centered approach, whereas the 2022–23 cohort ($n = 43$) underwent a combined TBL and PT approach. Following a three-month training period, theoretical exams and OSCE were administered. Student engagement was evaluated using the SCEQ, and satisfaction was assessed through SSS. Data were analyzed using independent t-tests, Mann-Whitney U tests, and χ^2 tests, with statistical significance set at $p < 0.05$.

Results No significant baseline differences were observed in demographics. TBL + PT cohort demonstrated significantly higher theoretical test scores and OSCE performance in most assessed skills, including pulpotomy, tooth preparation, incision and suturing, and patient intake. Engagement scores were also significantly higher in the domains of emotional engagement and participation/interaction, and overall student satisfaction improved, particularly regarding teaching quality and student-centric learning methods. Word cloud analyses of student feedback revealed a stronger emphasis on collaboration, participation, and innovation in the TBL + PT cohort compared to the traditional group.

Conclusions Incorporating Team-Based Learning and Peer Teaching into standardized dental residency training markedly enhanced theoretical knowledge, clinical proficiencies, and learner engagement. This instructional strategy improved residents' technical competencies and cultivated stronger team collaboration, communication, and higher satisfaction levels, offering a promising alternative to traditional teaching for residency training in oral medicine.

Keywords Team-based learning, Peer teaching, Student engagement, Standardized residency training, Oral medicine

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Introduction

Residency training is a critical phase for medical graduates to develop the skills and knowledge needed for professional practice, ensuring consistent standards among clinicians and improving healthcare quality. In China, the Standardized Training for Resident follows a "5 + 3" model: five years of medical education and three years of residency training in their choice of specialty [1]. Trainees must pass entrance exams, regular assessments, and the National Medical Practitioner Qualification Examination to complete the program.

Modern dental education in mainland China began in 1917 and has since become an integral part of medical education [2]. Its development has been increasingly prioritized in alignment with the country's economic and social progress. Students were admitted to bachelor's programs directly after high school [3]. Approximately 100 universities offer a five-year program, which include four years of theoretical and laboratory-based courses and one year of clinical internship.

In 2014, mainland China established a national standardized residency training system specifically for stomatology [4]. This program aims to enhance the practical skills and clinical competencies of dental graduates. Under the program, dental graduates are required to complete 36 months of clinical training across various disciplines. The standardized residency training in oral medicine primarily focuses on the prevention and management of diseases affecting dental hard tissues, periodontal tissues, oral mucosa, and underlying soft tissues. The training encompasses several specialties, including endodontics, periodontics, oral mucosal diseases, preventive dentistry, and pediatric dentistry. This program plays a pivotal role in fostering residents' comprehensive theoretical foundation, mastery of standardized and advanced clinical techniques, and development of sophisticated clinical reasoning skills [5].

Currently, the standardized residency training in oral medicine still predominantly relies on traditional teaching methods, yet these approaches have notable limitations. This teacher-centered model places trainees in a passive role, hindering active participation, teamwork, and self-directed learning. It emphasizes theoretical knowledge while lacking sufficient focus on clinical competencies such as communication, decision-making, and critical thinking. Additionally, the absence of peer-to-peer teaching and team-based learning limits knowledge integration and skill development, restricting the cultivation of well-rounded professionals needed in modern oral medicine.

Team-Based Learning (TBL) is an active learning strategy that engages small groups in applying conceptual knowledge through individual work, teamwork, and immediate feedback [6]. TBL is particularly well-suited for healthcare education as it facilitates the effective management of meaningful, multifaceted, and complex clinical scenarios through peer-guided case assessments and active problem-solving [7]. Peer teaching is an instructional strategy in which students teach and learn from each other [8]. As collaborative approaches, TBL have shown its ability to enhance students' knowledge, problem-solving abilities, and learning satisfaction, while also fostering teamwork, communication, and accountability across multiple disciplines compared to traditional methods [9–11]. When combined with peer-assisted learning, TBL has also been reported to improve teaching and communication skills, with most students expressing high levels of satisfaction and recommending the approach to their peers [12, 13]. Furthermore, research highlights the effectiveness of peer-assisted learning in dental education, demonstrating that it is well-received, enhances peer tutors' knowledge, and is as effective as staff-led teaching while fostering graduate attributes [14]. A UK study found that near-peer teaching in dental hygiene and therapy is a sustainable, low-cost method that enhances learning, relationships, and skills [15]. Although TBL and Peer Teaching may require more time for students and faculty preparation and face tutor variability [16], these challenges can be addressed through structured training, clear guidelines, and continuous feedback.

Based on this, the present study aims to explore the application and effectiveness of combining Team-Based Learning and Peer Teaching in oral medicine residency training. By integrating these collaborative approaches, the research seeks to provide evidence for improving professional competencies, promoting active learning, and offering new perspectives for stomatology education.

Materials and methods

Participants

This study was conducted at the Affiliated Stomatology Hospital of Guangzhou Medical University from 2021 to 2023. A total of 82 dental students from the 2021 and 2022 cohorts participated. All participants were full-time five-year undergraduate dental students who had completed their fifth-year clinical internship and were in their first year of standardized residency training. Prior to commencing clinical practice, the participants completed a one-week intensive preclinical training program comprising comprehensive theoretical instruction and hands-on practice with simulation models. All research methods were carried out in accordance with relevant guidelines and regulations.

Study design

The participants were divided into two groups: the 2021-22 cohort, which followed the traditional teaching

approach ($n = 39$), and the 2022-23 cohort, which received a combined TBL and PT approach ($n = 43$). To ensure consistency across both groups, all teaching sessions were conducted by the same faculty members. Faculty involvement, including feedback, direct guidance, and evaluation, was carefully monitored to ensure equality between the traditional teaching group and the TBL + PT group, with faculty in both cohorts providing structured feedback during practice sessions, clarifying misconceptions, and offering guidance during case discussions. Figure 1 illustrates the flowchart of this study.

In the traditional teaching group, the training was conducted using a teacher-centered approach, focusing on the delivery of theoretical knowledge and basic clinical skills in oral medicine. Theoretical learning was primarily delivered through teacher-led lectures, with each session consisting of a one-hour systematic explanation of core topics, such as endodontics, periodontics, and oral mucosal diseases, followed by a 30-minute case analysis. Teaching was supplemented with PPT presentations and textbooks. Clinical skill training was conducted through instructor demonstrations, followed by students

practicing on simulation models. Instructors provided individual guidance, correcting errors during the practice sessions to ensure the students developed proficiency in fundamental clinical procedures.

In the TBL + PT group, theoretical learning followed the TBL structure, where students completed pre-class preparation by reviewing assigned materials and taking online test. During class, individual readiness assurance tests (IRAT) and team readiness assurance tests (TRAT) were conducted to consolidate knowledge, followed by group discussions of complex clinical cases and presentations under the guidance of instructors. Clinical skill training incorporated the PT model, where students worked collaboratively within teams to learn and practice clinical skills. Some team members were responsible for demonstrating procedures, while others observed, practiced, and provided feedback. Peer evaluation and feedback were implemented through structured sessions where team members observed each other's performance during clinical practice, identified strengths and areas for improvement, and provided constructive suggestions for refinement. Instructors actively monitored these
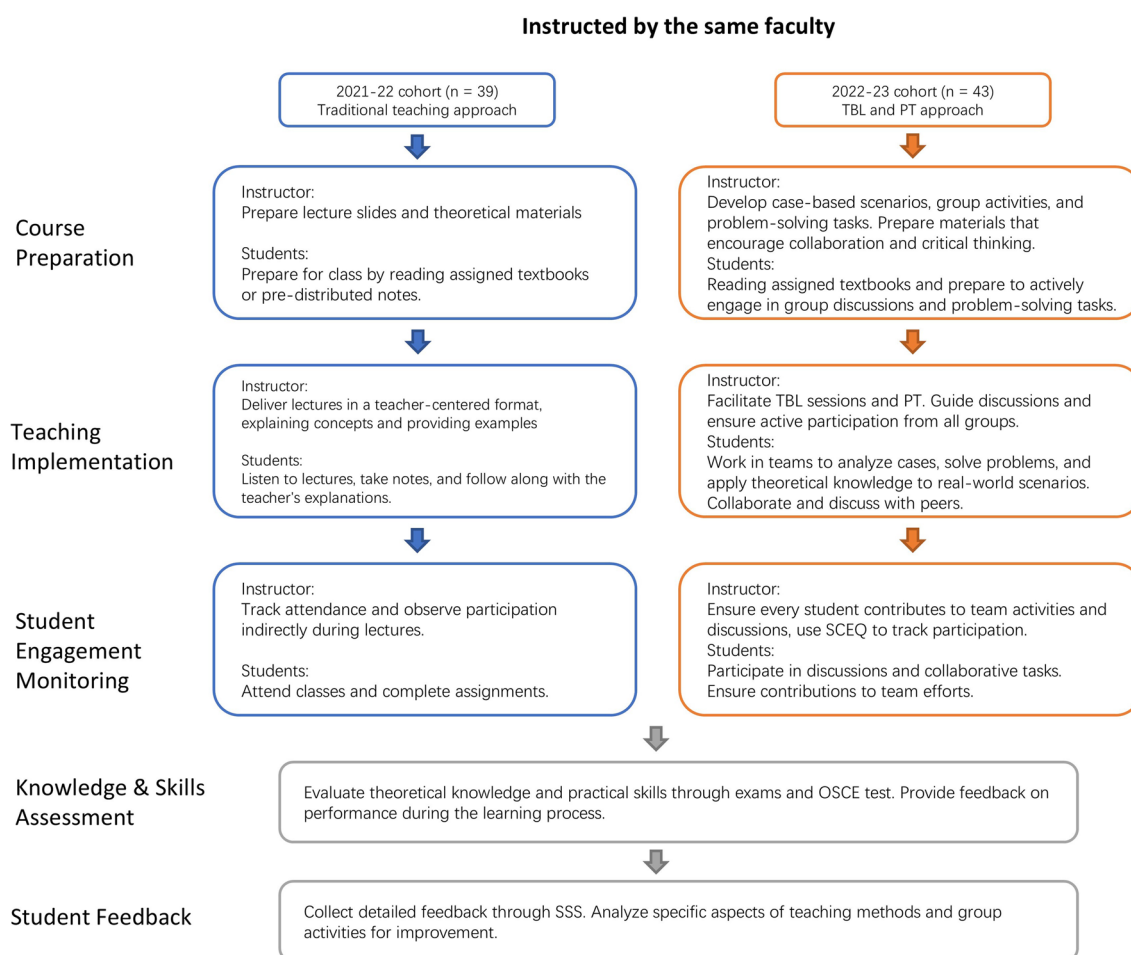

Fig. 1 Flowchart of the study

interactions, intervening when necessary to clarify misconceptions, demonstrate correct techniques, and provide targeted guidance.

Course assessments

The theoretical knowledge assessment was conducted to evaluate students' comprehension and application of core concepts in oral medicine. This component included a written examination comprising multiple-choice questions, short-answer questions, and case-based questions. The exam covered key topics such as endodontics, periodontics, and oral mucosal diseases, ensuring alignment with the course objectives. Additionally, pre- and post-course tests were administered to measure knowledge acquisition and assess the effectiveness of the instructional approaches.

The clinical skills assessment was performed using an Objective Structured Clinical Examination (OSCE), a multi-station assessment method designed to evaluate students' practical competencies in oral medicine. Each OSCE station focused on specific clinical tasks, such as performing root canal treatments, periodontal scaling, or diagnosing oral mucosal conditions. Students were assessed based on their technical accuracy, adherence to procedural protocols, and ability to explain their clinical reasoning. Immediate feedback was provided at each station to facilitate skill improvement and ensure the development of standardized clinical techniques.

Student engagement during the course was measured using the Student Course Engagement Questionnaire (SCEQ), which evaluates four key dimensions: skills engagement, emotional engagement, participation/interaction engagement, and performance engagement [17]. Students rated their involvement in activities such as pre-class preparation, active participation in discussions, and teamwork during collaborative tasks. The SCEQ provided insights into the effectiveness of the instructional methods in fostering active learning and maintaining student interest throughout the course [18].

Student satisfaction was assessed using the Student Satisfaction Survey (SSS), which examined students' perceptions of the course design, teaching quality, learning environment, and overall learning experience. The survey included Likert-scale items covering areas such as the clarity of course objectives, the relevance of course content, the effectiveness of teaching methods, and the adequacy of learning resources. The SSS results provided valuable insights for identifying strengths and areas for improvement in the course structure and delivery [19]. Open-ended question was not included in the current study.

At the end of the course, all participating students were invited to anonymously evaluate their overall learning experience by selecting and submitting a set of keywords that best represented their feelings and thoughts about the course. These anonymized submissions were then collected and compiled into a comprehensive dataset. Utilizing the WordArt.com platform, word clouds were generated for each group based on the frequency of the submitted keywords.

Statistical analysis

Statistical analyses were performed using R software (version 4.3.1) and GraphPad Prism (version 9). Descriptive statistics were used to summarize demographic data and baseline information. Chi-square test was employed to evaluate differences in gender proportions between groups, whereas the independent t-test was utilized to assess group differences in age and entrance examination scores. Theoretical test scores, OSCE scores and Engagement (SCEQ) were analyzed using independent t-tests. Satisfaction (SSS) scores were analyzed using Mann-Whitney U tests. For correlation analysis, the Shapiro-Wilk test was first used to assess normality. Subsequently, Pearson correlation analysis was performed. Data visualization, including bar plots and boxplots, was conducted using GraphPad. To control for the false discovery rate (FDR) across multiple comparisons (comparisons in clinical skills assessment, engagement assessment, and student satisfaction survey), the Benjamini-Hochberg correction was applied. Adjusted p-values are reported where applicable. P-value of < 0.05 was considered statistically significant.

Results

Demographics and baseline information of the students

A total of 82 undergraduate students were recruited for this study, with 39 students in the 2021-22 cohort and 43 students in the 2022-23 cohort. Demographic and baseline information of the students are summarized in Table 1. No statistically significant differences were observed between the two cohorts in gender distribution ($\chi^2 = 0.0104$, $P = 0.918$), age (22.9 ± 0.88 vs. 23.1 ± 0.91 years; $t = 1.011$, $P = 0.315$), or entrance exam scores (82.4 ± 8.41 vs. 83.5 ± 7.62; $t = 0.617$, $P = 0.539$). These findings demonstrate the baseline equivalence of the two cohorts, ensuring comparability for subsequent analyses.

Table 1 Demographics and baseline information of the students

	2021-22 cohort	2022-23 cohort	t/χ^2	P value
Total student numbers	39	43		
Gender			0.0104	0.918
Male	15	17		
Female	24	26		
Age (years), mean ± SD	22.9 ± 0.88	23.1 ± 0.91	1.011	0.315
Entrance exam scores	82.4 ± 8.41	83.5 ± 7.62	0.617	0.539

Theoretical knowledge assessment

Theoretical knowledge assessment was conducted in a format similar to the national residency training completion examination. The comparison of pre- and post-course test scores between the two cohorts were shown in Fig. 2. No significant difference was observed in scores before standardized residency training (83.5 ± 7.62 vs. 82.4 ± 8.41, $P > 0.05$). After 3-month training, the 2022-23 cohort, which received the TBL + PT teaching approach, demonstrated significantly higher theoretical test scores compared to the 2021-22 cohort (83.74 ± 6.60 vs. 73.46 ± 8.68, $P < 0.001$) (Fig. 3).

Clinical skills assessment

In the TBL + PT group, the training employed a collaborative teaching approach to enhance students' active learning capabilities and teamwork skills. The 2022-23 cohort, exhibited significantly higher overall performance in clinical skills compared to the 2021-22 cohort (Total score: 85.09 ± 2.43 vs. 76.70 ± 4.18, $P < 0.001$), as shown in Table 2; Fig. 2.

Patient Intake represent a comprehensive station assessing critical aspects of patient management, including medical history taking and clinical examination, medical record documentation, and doctor-patient communication. A marked improvement was found in the 2022-23 cohort (93.00 ± 2.61 vs. 73.36 ± 6.96, $P < 0.001$). These findings highlight the advantages of active learning strategies in fostering communication skills, clinical reasoning, and professionalism.

For technical skills assessed via the OSCE, the TBL + PT (2022-23) cohort consistently outperformed the traditional cohort across multiple stations. In Pulpotomy, Tooth Preparation, Incision and Suturing, as well as Curettage, the TBL + PT cohort achieved significantly higher scores than traditional teaching cohort (88.30 ± 3.81 vs. 76.92 ± 7.91, $P < 0.001$; 90.93 ± 2.20
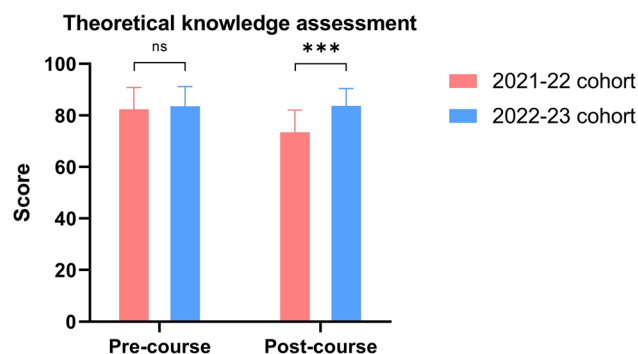

Fig. 2 Pre- and post-course theoretical knowledge test scores between 2021-22 and 2022-23 cohorts

Table 2 Clinical skills assessment of the students

	2021-22 cohort	2022-23 cohort	t	*P* value
Patient Intake	73.36 ± 6.96	93.00 ± 2.61	-15.13	< 0.001
Pulpotomy	76.92 ± 7.91	88.30 ± 3.81	-8.19	< 0.001
Tooth Preparation	76.18 ± 8.20	90.93 ± 2.20	-9.29	< 0.001
Incision and Suturing	79.00 ± 7.21	91.00 ± 2.83	-8.15	< 0.001
Curettage	73.64 ± 7.66	84.00 ± 4.08	-6.91	< 0.001
Rubber Dam	78.33 ± 7.54	79.35 ± 8.03	-0.57	0.569
Periodontal Probing	76.13 ± 8.17	77.12 ± 8.44	-0.54	0.591
Total score	76.70 ± 4.18	85.09 ± 2.43	-10.91	< 0.001

vs. 76.18 ± 8.20, $P < 0.001$; 91.00 ± 2.83 vs. 79.00 ± 7.21, $P < 0.001$; 84.00 ± 4.08 vs. 73.64 ± 7.66, $P < 0.001$ respectively), reflecting superior mastery of procedural accuracy, adherence to clinical protocols, and critical understanding of key techniques in students who in TBL + PT cohort.

However, no significant differences were observed in Rubber Dam Placement (79.35 ± 8.03 vs. 78.33 ± 7.54, $P = 0.569$) or Periodontal Probing (77.12 ± 8.44 vs. 76.13 ± 8.17, $P = 0.591$), suggesting that these routinely
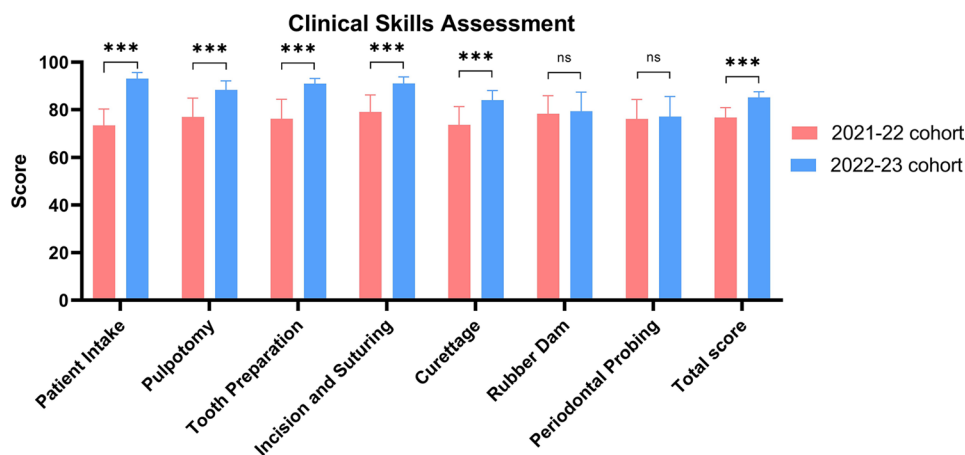

Fig. 3 Clinical skills assessment of the students

practiced skills may not have been as influenced by the advanced teaching methodology.

Student engagement

The SCEQ was used to assess the level of student engagement. The comparison of four key dimensions of engagement scores between the 2021-22 and 2022-23 cohorts is presented in Table 3.

While the 2022-23 cohort showed higher scores in skills engagement (33.1 ± 7.14 vs. 30.2 ± 6.88), the difference was not statistically significant ($P = 0.064$). However, significant improvements were observed in emotional engagement (20.6 ± 2.86 vs. 17.7 ± 3.76, $P < 0.001$) and participation/interaction engagement (25.5 ± 3.38 vs. 22.4 ± 4.12, $P < 0.001$), suggesting that the active and collaborative teaching strategies fostered stronger emotional connections and greater teamwork among students. Performance engagement scores were comparable between the two cohorts (12.3 ± 1.69 vs. 12.4 ± 1.77, $P = 0.794$), indicating that both teaching methods had a similar influence on this dimension. Notably, the total engagement score was significantly higher in the TBL + PT cohort (91.5 ± 8.57) compared to the traditional cohort (82.7 ± 9.03, $P < 0.001$), highlighting the effectiveness of the TBL + PT model in increasing student engagement and promoting active learning during oral medicine residency training.

The correlation between student engagement (SCEQ scores) and academic outcomes (theoretical test scores) were further evaluated with Pearson correlation analysis. The results showed a significant positive correlation in both the 2021–22 cohort ($r = 0.7235$, $p < 0.0001$) and the 2022–23 cohort ($r = 0.6727$, $p < 0.0001$), indicating that higher levels of student engagement were associated with better academic performance.

Student satisfaction

The results of the Student Satisfaction Survey (SSS) revealed a significant difference in satisfaction scores between the two groups (t = -3.13, $P = 0.0025$). The traditional teaching group had an average SSS total score of 60.6 ± 4.32, while the group utilizing the new teaching method scored significantly higher at 63.4 ± 3.73.

Table 3 Engagement assessment of the students

Dimensions	2021-22 cohort	2022-23 cohort	t	P value
Skills Engagement	30.2 ± 6.88	33.1 ± 7.14	-1.872	0.064
Emotional Engagement	17.7 ± 3.76	20.6 ± 2.86	-3.902	< 0.001
Participation/Interaction	22.4 ± 4.12	25.5 ± 3.38	-3.699	< 0.001
Performance Engagement	12.4 ± 1.77	12.3 ± 1.69	0.262	0.794
Total Score	82.7 ± 9.03	91.5 ± 8.57	-4.515	$p < 0.001$

Further analysis identified specific survey items with significant differences between the two cohorts (Table 4). Students in the 2022-23 cohort reported higher satisfaction with the teaching and mentoring process (Question 8, t = -2.082, $P = 0.0398$), the institution's efforts to improve teaching quality (Question 15, t = -2.22, $P = 0.029$), and the use of student-centric teaching methods (Question 16, t = -3.14, $P = 0.0023$). These findings collectively highlight the potential of innovative teaching strategies to not only improve overall satisfaction but also address specific domains of the educational experience, including mentoring, continuous quality improvement, and the adoption of student-centric learning methods.

Students' feedback

The word clouds shown in Fig. 4 illustrate the key themes from students' feedback for 2 cohorts. In the 2021–22 cohort, students frequently highlighted terms such as "comprehensive," "experienced," "clear," and "thorough," reflecting their appreciation for structured and detailed course content as well as the professionalism and expertise of the instructors. In contrast, the 2022–23 cohort emphasized terms like "teamwork," "collaboration," "participation," and "innovative," suggesting a shift in focus toward active learning, peer interaction, and innovative teaching approaches. These differences indicate that while both cohorts valued the quality of their educational experiences, the 2022–23 cohort benefited more from interactive and collaborative learning methodologies (Fig. 5).

Table 4 SSS total scores and questions with significant differences in results

Questions	2021-22 cohort	2022-23 cohort	t	P value
8.The teaching and mentoring process in your institution facilitates you in cognitive, social and emotional growth.	3.17 ± 0.59	3.44 ± 0.54	-2.082	0.0398
15.The institution makes effort to engage students in monitoring, review and continuous quality improvement of the teaching-learning process.	3.12 ± 0.64	3.41 ± 0.53	-2.22	0.029
16.The institute/teachers use student centric methods, such as experiential learning, participative learning and problem solving.	3.07 ± 0.65	3.46 ± 0.49	-3.14	0.0023
Total Score	61.6 ± 4.32	64.4 ± 3.73	-3.13	0.0025

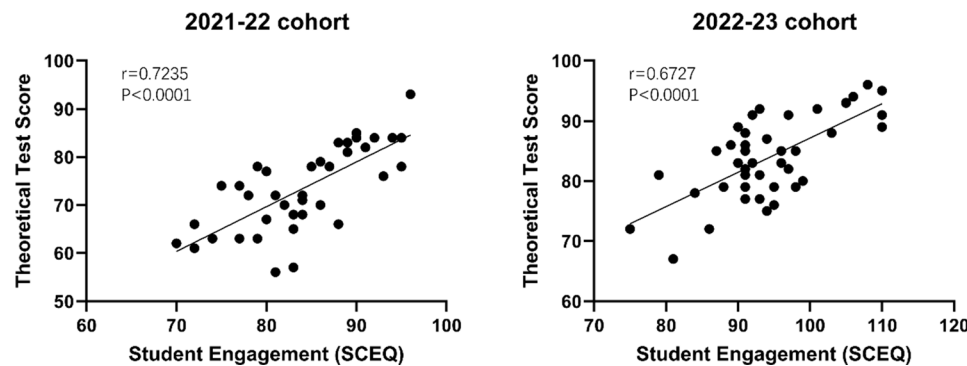**Fig. 4** Correlation between student engagement (SCEQ) and theoretical test scores in the 2021–22 and 2022–23 cohorts
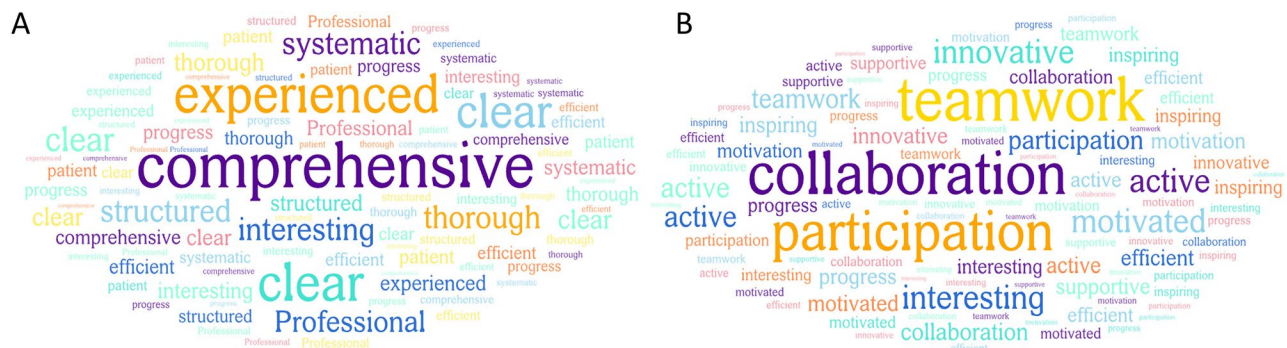

Fig. 5 Word clouds of the (**A**) 2021-22 cohort and (**B**) 2022-23 cohort

Disscussion

This study compared the traditional teacher-centered approach with a combined team-based learning and peer teaching model in the context of dental residency training. Our findings indicate that the TBL + PT cohort outperformed the conventional cohort in theoretical knowledge, clinical skill acquisition, and student engagement metrics, which are consistent with prior studies employing TBL and PT frameworks [20–24]. Such results underscore the potential of learner-centered, collaborative pedagogies in enhancing critical competencies among dental residents, offering valuable insights for curricular optimization in oral medicine training.

The standardized residency training program represents an essential phase in the professional development of dental graduates, facilitating their transition into competent clinical practitioners. It serves as a vital bridge between foundational theoretical knowledge and its application in clinical practice, playing a pivotal role in the cultivation of highly skilled dental professionals [25]. Given their limited prior clinical exposure, most residents—whether recent medical graduates or professional master's candidates—face the critical challenge of deepening their understanding, refining practical skills, and translating theoretical knowledge into comprehensive diagnostic and therapeutic competencies tailored to patient-specific clinical scenarios [26]. Therefore, it

is imperative to integrate effective teaching methodologies into residency training programs to equip residents with the clinical competencies required for independent practice.

The TBL + PT cohort outperformed the traditional group in theoretical and OSCE scores, attributed to TBL's structured design and peer-led demonstrations. These methods foster deeper cognitive engagement, long-term knowledge retention, psychomotor skill development, and a supportive learning environment [27, 28], aligning with adult learning theories and social constructivist principles [29, 30]. This approach encourages learners to actively engage with content, apply theoretical knowledge, and collaboratively solve problems, thereby promoting higher-order thinking. This dynamic reduces learner inhibitions, fosters a "teach-to-learn" effect, and consolidates both theoretical understanding and practical skills [31, 32]. Furthermore, the observed increases in emotional engagement and interactive participation suggest that collaborative learning strengthens interpersonal bonds and collective responsibility—essential attributes in oral medicine, where multidisciplinary teamwork and effective communication are vital to patient care [33, 34].

These mechanisms help explain the significant improvements in most assessed domains following TBL + PT implementation. However, routine procedures such as rubber dam application and periodontal probing

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did not show marked differences ($P = 0.569$ and $P = 0.591$, respectively) between the two cohorts. This could be attribute to the minimal cognitive and limited instructor intervention demands for these skills. Additionally, students are likely to entered the residency training with a solid foundation in these tasks from prior undergraduate practice. This suggests that instructional methods may have a more limited impact on highly practiced, routine skills. On the other hand, TBL + PT shows greater advantages in tasks requiring complex skills involving higher cognitive and psychomotor integration. This highlights the potential of team-based strategies to enhance challenging clinical competencies, reinforcing their value in residency training.

The significant improvement in student engagement observed in the TBL + PT cohort highlights the effectiveness of collaborative and learner-centered teaching strategies. The strong positive correlation between SCEQ scores and theoretical test scores further underscores the central role of engagement in academic success. These results suggest that fostering engagement through approaches like TBL + PT not only enhances interpersonal and problem-solving skills but also directly contributes to theoretical knowledge acquisition, emphasizing the importance of engagement-focused pedagogies in residency training.

Based on the student feedback and Satisfaction Survey results, the TBL + PT cohort demonstrated a significant increase in satisfaction regarding teaching guidance, quality improvement efforts, and self-directed learning. These findings suggest that the innovative instructional strategy not only strengthens learning motivation and teamwork but also enhances overall teacher–student interaction and the educational experience. The word cloud generated from students' open-ended comments also underscored this positive sentiment by highlighting recurrent terms such as "collaboration," "peer support," "interactive," and "confidence" in TBL + PT group. These findings align with the core principles of TBL + PT, fostering active engagement, interpersonal skills, and enhancing problem-solving and communication skills that are essential for clinical practice. While not fully captured by quantitative measures, these soft skills are vital to professional competency and underscore the value of collaborative strategies in residency training.

Notwithstanding the promising findings, several limitations warrant attention. The relatively small, single-center sample size restricts broader application of the results. Differences in educational resources, cultural contexts, and regions may impact the findings in teaching effectiveness [16]. Although baseline characteristics showed no significant differences, cohort grouping by academic year may have introduced unmeasured variables, including societal shifts or changes in student mindset,

confounding factors such as prior knowledge, learning styles, and individual motivation may also have influenced the results. Individual variations in instructors' teaching styles and interactions, despite efforts to ensure consistency, may also have introduced variability. suggesting the need for standardized instructor training in future studies. Taken together, these limitations suggest the need for large-scale, multi-center studies conducted across different institutions and regions, with standardized instructor training, control of baseline characteristics and compounding factors to validate the findings and ensure their broader applicability. Another limitation lies in the inherent constraints of the residency training program, where residents typically rotate through each department for a duration of only 3–6 months, which expose residents to varied teaching styles across departments, complicating the consistent implementation of instructional strategies. Such variability may hinder the uniform implementation of structured instructional strategies. Furthermore, the study mainly focusses on students' academic performance, engagement, and satisfaction, yet it overlooks critical evaluations from educators and feedback from healthcare institutions, both of which are well-established as integral factors influencing teaching effectiveness and should be explored in future research [35, 36].

In conclusion, this study demonstrates that integrating team-based learning and peer teaching into dental residency training significantly enhances theoretical knowledge, clinical skills, and student engagement. By fostering higher-order thinking, psychomotor skill development, and collaborative learning, TBL + PT addresses limitations of traditional approaches and better prepares residents for independent clinical practice. While further multi-center studies are needed to validate these findings, this study highlights the potential of innovative teaching strategies to optimize residency training outcomes.

Abbreviations
TBL   Team-Based Learning
PT   Peer Teaching
OSCE   Objective Structured Clinical Examination
SCEQ   Student Course Engagement Questionnaire
SSS   Student Satisfaction Survey
IRAT   Individual Readiness Assurance Tests
TRAT   Team Readiness Assurance Tests

Supplementary Information

Supplementary Material 1

Supplementary Material 2

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Data availability
The data sets generated during or analyzed during this study are available from the corresponding author upon reasonable request.

Declarations

Ethics approval and consent to participate
Study compliant/adhered to Helsinki Declaration. Study received ethical approval by the ethics committee of the affiliated stomatological hospital of Guangzhou medical university (Approval Number: JXYJ20250303001). Informed oral consent to participate was obtained from all participants prior to their enrollment in the study. The ethics committee approved the use of oral consent as sufficient for this study due to it primarily involved routine educational activities and surveys without any invasive procedures or interventions.

Consent for publication
Not applicable. There are no details on individuals reported within the manuscript.

Competing interests
The authors declare no competing interests.

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