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Learner-centered SNAPPS model and its impact on diagnostic thinking among dental students

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Abstract

Background & Objective: Diagnostic thinking is a core skill for accurate diagnosis and treatment and is essential for all medical students. This study aimed to investigate the impact of learner-centered education using the Student-centered, Narrow, Analyze, Probe, Plan, Select (SNAPPS) approach on the diagnostic thinking skills of dental students.

Materials & Methods: This pretest–posttest quasi-experimental study was conducted on 49 dental students in the second semester of the 2022–2023 academic year, after obtaining informed consent. Students' diagnostic thinking was assessed before the educational intervention using Bordage's standard Diagnostic Thinking Inventory (DTI). Then, students were trained using the SNAPPS clinical teaching method and re-evaluated with the same questionnaire. Data were analyzed using paired t-test in SPSS (version 26).

Results: 59.2% of the students were male, 87.8% were single, and 73.5% were non-native. The mean ± standard deviation of the participants' age was 25.04 ± 3.56 years. The mean ± standard deviation of flexibility in thinking increased from 76.89 ± 10.54 before the intervention to 84.16 ± 10.77 after the intervention ($p < 0.001$). The mean ± standard deviation of structure of knowledge in memory increased from 67.78 ± 8.77 to 71.02 ± 9.89 ($p = 0.024$). The mean ± standard deviation of the total DTI score increased from 145.45 ± 16.89 to 155.77 ± 18.35 ($p = 0.001$). The effect size (Cohen's $d = 0.522$) indicated a medium effect according to Cohen's classification.

Conclusion: The findings of this study indicate that the use of the SNAPPS model was associated with improvements in students' diagnostic thinking, including flexibility in thinking and structure of knowledge in memory.

Keywords: education, dental, clinical reasoning, problem based learning, students, dental, SNAPPS model

Introduction

Diagnostic thinking, a core competency for healthcare professionals, is the process of interpreting patient data to formulate an accurate diagnosis, a process closely linked to clinical reasoning [1, 2]. This complex skill integrates knowledge, communication, technical abilities, and values to provide effective care and is a critical component of medical education [3, 4]. While the acquisition of these skills is vital for graduates, many students currently learn them informally during clinical rotations [5]. Clinical reasoning is a broad logical thinking process that guides the health providers to take purposeful steps in diagnosis and treatment. This process exists in all stages of dealing with the patient, from the initial stage of getting the history of the disease to the patient's management and follow-up [6]. In contrast, diagnostic thinking refers specifically to the cognitive

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processes involved in generating, evaluating, and selecting diagnostic hypotheses to reach an accurate diagnosis. Diagnostic thinking relies on rich and distinct knowledge to create mental models of symptoms and findings, leading to a systematic diagnosis [7]. Therefore, diagnostic thinking represents a fundamental component of the broader clinical reasoning process.

Current conventional teaching often relies on students' application of clinical reasoning during clinical rotations as part of a hidden curriculum, which can be highly variable, unstructured, and non-standardized, with limited faculty oversight and few opportunities for feedback [8]. Fostering effective clinical reasoning requires appropriate clinical teaching strategies to improve knowledge, data-gathering skills, data processing, metacognition, reflection, and professional socialization [9]. Clinical teaching refers to instruction during patient visits for prevention, diagnosis, treatment, or follow-up, which takes place in a clinic without hospital admission. This type of education, like other teaching methods, has successes and failures, which, if a proper and scientific model is not followed, can cause many problems [10].

One of the clinical teaching models that can cultivate clinical reasoning is the Student-centered, Narrow, Analyze, Probe, Plan, Select (SNAPPS) model, introduced in 2003 by Wolpaw [11]. This model consists of six stages: (1) Summarize the patient's history, (2) Narrow the differential diagnoses to two or three relevant probabilities, (3) Analyze the differential diagnoses by comparing and contrasting probabilities, (4) Probe the preceptor about uncertainties, difficulties, or alternative approaches, (5) Plan and manage the patient's treatment issues, and 6) Select a related topic for self-directed learning [12]. Chen et al. investigated the effectiveness of SNAPPS combined with the One-Minute Preceptor (OMP) teaching method compared with other teaching methods among medical students and reported significantly higher theoretical test scores among senior medical students in the intervention group than in the control group [13]. Ramazanzade and Ebrahimzade compared SNAPPS with conventional clinical teaching among medical students and concluded that the SNAPPS model was effective in developing clinical reasoning skills [14].

In addition, the SNAPPS method has been reported to enhance clinical diagnostic reasoning during case presentations in family medicine outpatient clinics [15].Although SNAPPS has been extensively explored in medical education, the evidence for its use in dentistry education is lacking [16]. Dental students face specific diagnostic challenges, such as interpreting oral findings, evaluating radiographs, and incorporating patient history into clinical decision-making. As a result, educational strategies that promote diagnostic thinking may increase the quality of dental clinical training. Investigating the efficacy of SNAPPS among dental students may yield useful evidence for enhancing clinical teaching strategies in dentistry [17]. Although previous studies have reported the effectiveness of SNAPPS in improving clinical reasoning [14], evidence regarding its effect on diagnostic thinking among dental students remains limited. In particular, little is known about its potential effect on the two DTI domains, namely flexibility in thinking and structure of knowledge in memory. To the best of our knowledge, no previous study has specifically examined the effect of the SNAPPS approach on diagnostic thinking among dental students. Therefore, this study aimed to determine the effect of learner-centered education using the SNAPPS approach on the diagnostic thinking skills of dental students at Zanjan University of Medical Sciences.

Materials & Methods

Design and setting(s)

This quasi-experimental study with a pretest-posttest design was conducted at the School of Dentistry, Zanjan University of Medical Sciences, in the Department of Oral Diseases during the second semester of the 2022–2023 academic year. The study was conducted from February 4, 2023, to June 5, 2023. The clinical training was organized into eight rotations, with each rotation consisting of 6–7 students. Each group participated in clinical training in the Department of Oral Diseases for 2 weeks.

Participants and sampling

The study population consisted of all dental students at Zanjan University of Medical Sciences who were enrolled in the Practical Oral Diseases course during the second semester of the 2022–2023 academic year. All eligible students enrolled in the Practical Oral Diseases course during the second semester of the 2022–2023 academic year were invited to participate using a census sampling method. A total of 49 students participated in the study. Students who dropped the course during the semester or had incomplete course records were excluded. All participants provided informed consent before participation. The study flow is presented in **Figure 1**.

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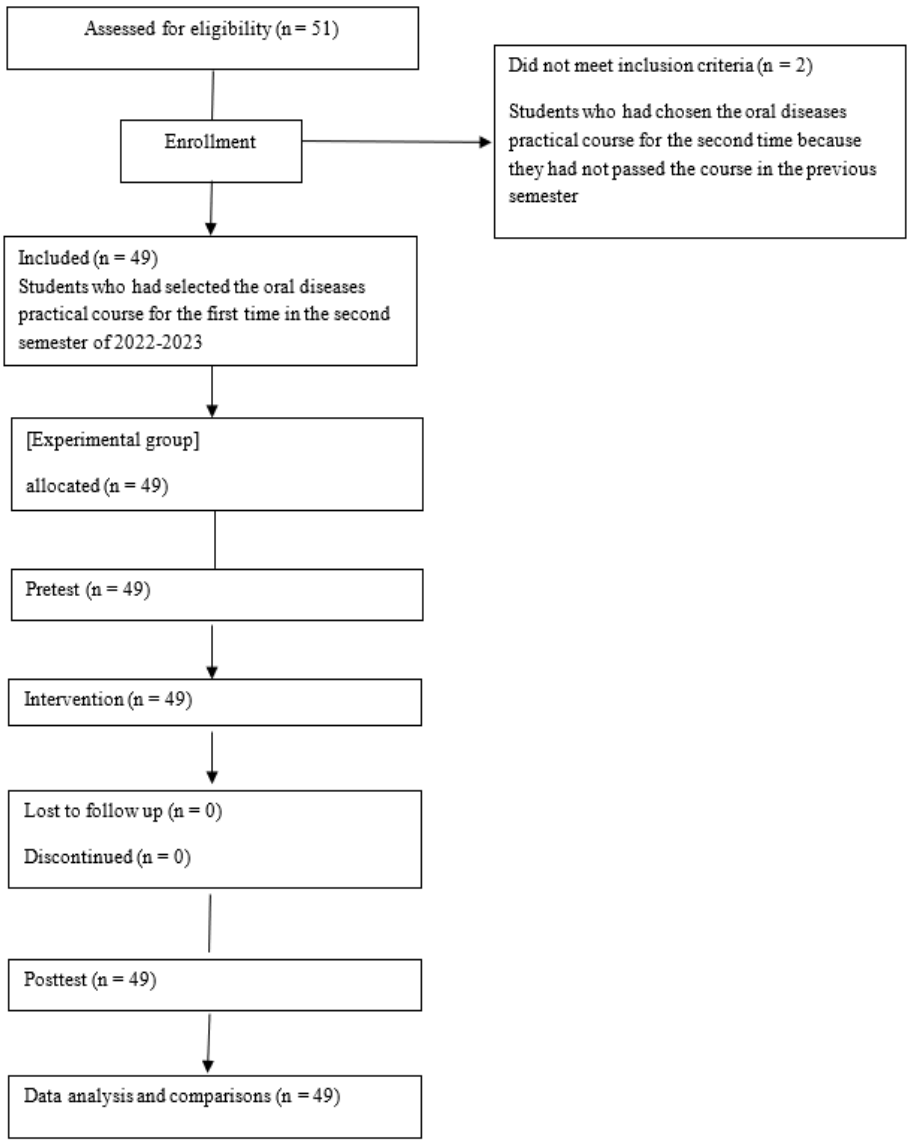

Figure 1. Flow diagram for the study

Tools/Instruments

The Diagnostic Thinking Inventory (DTI) developed by Bordage et al. was used in this study. This questionnaire has been widely used to assess diagnostic reasoning skills in various groups of medical students and physicians in different settings [19]. The questionnaire consists of two parts: demographic questions and DTI questions. The DTI section is composed of 41 questions (21 questions in the domain of "flexibility in thinking" and 20 questions in the domain of "structure of knowledge in memory"). Each item includes a stem and a semantic-differential response format, rated on a 6-point Likert scale. The DTI assesses two domains of diagnostic thinking: (a) flexibility in thinking and (b) structure of knowledge in memory [19]. Total DTI scores can range from a minimum of 41 to a maximum of 246 (flexibility in thinking: 21 to 126; structure of knowledge in memory: 20 to 120). The DTI has demonstrated adequate validity and reliability for differentiating between novice and experienced diagnosticians, with a reported Cronbach's alpha of 0.83 [19]. The Persian version of the questionnaire has also been evaluated for validity and reliability in previous studies [20, 21]. In the present study, the internal consistency reliability of the instrument was assessed using Cronbach's alpha. The obtained Cronbach's alpha of 0.81 indicated acceptable internal consistency for assessing diagnostic thinking among dental students.

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Data collection methods

Before the training course, students' diagnostic thinking was assessed using the DTI developed by Bordage and colleagues (pretest). Students then received training using the SNAPPS clinical teaching method over a 2-week rotation period. The training was conducted by a specialist professor in oral diseases as a facilitator in the Department of Oral Diseases. At the end of the 2-week course, the posttest was conducted using the same DTI questionnaire.

Data analysis

Collected data were entered into SPSS software version 26. Descriptive statistics (frequency, relative frequency for qualitative data; mean and standard deviation for quantitative data) were reported. For inferential analysis, the Kolmogorov-Smirnov test was used to assess the normality of the distribution of quantitative variables. The results showed that data distribution was normal. To compare the scores of the diagnostic thinking domains before and after the training, a paired t-test and effect size analysis were used.

Results

A total of 49 students participated in this study, all of whom were enrolled in the Practical Oral Diagnosis course. The questionnaire demonstrated good internal consistency reliability (Cronbach's alpha = 0.81).

The findings indicated that 59.2% (n = 29) of the students were male, and 40.8% (n = 20) were female. Regarding marital status, 87.8% (n = 43) were single, and 12.2% (n = 6) were married. In terms of residency status, 73.5% (n = 36) of the participants were non-native, while 26.5% (n = 13) were native to the area. The mean ± standard deviation for age was 25.04 ± 3.56 years, and that for academic Grade Point Average (GPA) was 16.18 ± 1.01 (**Table 1**).

Table 1. Descriptive characteristics of participating dental students (n = 49)

Variable	Category	Frequency	Percent (%)
Gender	Male	29	59.2
	Female	20	40.8
Marital status	Married	6	12.2
	Single	43	87.8
Residency status	Native	13	26.5
	Non-native	36	73.5
GPA	Minimum	13.00	—
	Maximum	18.73	—
	Mean	16.18	—
	SD	1.01	—
Age (years)	Minimum	22.00	—
	Maximum	36.00	—
	Mean	25.04	—
	SD	3.56	—

Note: All students were enrolled in the Practical Oral Diagnosis course during the second semester of the 2022–2023 academic year.
Abbreviations: GPA, grade point average; SD, standard deviation.

The mean ± standard deviation for "flexibility in thinking" before the intervention was 76.89 ± 10.53, and after the intervention, it was 84.16 ± 10.77. A paired t-test showed that the mean score for this domain significantly increased after the intervention ($p < 0.001$; **Table 2**).

Table 2. Comparison of flexibility in thinking scores before and after the SNAPPS intervention

Variable	Time	n	Minimum	Maximum	Mean	SD	SE	Sig.
Flexibility in thinking	Pre	49	45.00	98.00	76.89	10.53	1.59	t = - 4.113
	Post	49	63.00	117.00	84.16	10.77	1.62	p < 0.001

Note: Paired t-test was used to compare pre- and post-intervention scores.
Abbreviations: SD, standard deviation; SE, standard error; n, number of participants; Sig., statistical significance.

The mean ± standard deviation for "structure of knowledge in memory" before the intervention was 67.77 ± 8.76, and after the intervention, it was 71.02 ± 9.88. A paired t-test indicated that the mean score for this domain also significantly increased after the intervention ($p = 0.024$; **Table 3**).

The mean ± standard deviation for total DTI scores before the intervention was 145.45 ± 16.88, and after the intervention, it was 155.77 ± 18.35. The paired t-test revealed that the mean total DTI score significantly increased after the intervention ($p < 0.001$) (**Table 4**). The effect size (Cohen's d = 0.522) fell within the medium effect range according to Cohen's criteria, suggesting that the intervention produced a substantial and meaningful improvement in diagnostic thinking scores (**Table 5**).

Table 3. Comparison of structure of knowledge in memory scores before and after the SNAPPS intervention

Variable	Time	n	Minimum	Maximum	Mean	SD	SE	Sig.
Structure of knowledge in memory	Pre	49	48.00	95.00	67.77	8.76	1.25	t = - 2.331
	Post	49	50.00	95.00	71.02	9.88	1.41	p = 0.024

Note: Paired t-test was used to compare pre- and post-intervention scores.
Abbreviations: SD, standard deviation; SE, standard error; n, number of participants; Sig., statistical significance.

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Table 4. Comparison of total DTI scores before and after the SNAPPS model intervention

Variable	Time	n	Minimum	Maximum	Mean	SD	SE	Sig.
Total scores	Pre	49	96.00	188.00	145.45	16.88	2.55	t = - 3.463
	Post	49	120.00	198.00	155.77	18.35	2.77	p < 0.001

Note: Paired t-test was used to compare pre- and post-intervention scores.
Abbreviations: SD, standard deviation; SE, standard error; n, number of participants; Sig., statistical significance.

Table 5. Effect sizes of the SNAPPS model intervention

Variable	Pre-test Mean ± SD	Post-test Mean ± SD	Mean Difference (95% CI)	Sig.	Effect Size (Cohen's d)
Flexibility in thinking	76.89 ± 10.53	84.16 ± 10.77	- 7.27 (- 10.83 to - 3.70)	t = - 4.11, p < 0.001	0.620
Structure of knowledge in memory	67.77 ± 8.76	71.02 ± 9.88	- 3.24 (- 6.04 to - 0.44)	t = - 2.33, p = 0.024	0.333
Total DTI score	145.45 ± 16.88	155.77 ± 18.35	- 10.32 (- 16.32 to - 4.31)	t = - 3.46, p = 0.001	0.522

Note: Effect sizes were calculated using Cohen's d based on pre- and post-test scores. Paired t-test was used to compare pre- and post-intervention values.
Abbreviations: SD, standard deviation; CI, confidence interval; Sig., statistical significance; DTI, diagnostic thinking inventory.

Discussion

The primary goal of dental education is to develop health professionals who can maintain and improve the oral health of individuals and populations. Therefore, an important responsibility of educational policymakers and administrators is to evaluate the effectiveness of dental education in improving oral health outcomes in both the short and long term. Appropriate teaching of dental courses can contribute to the early diagnosis of oral lesions and ultimately improve the quality of community health services. Therefore, research on effective approaches to dental education is particularly important. Various teaching methods have consequently been investigated in medical and dental education. Innovative teaching methods in dentistry and medicine encompass a wide range of techniques and approaches designed to enhance students' learning experiences [22, 23].

The findings of the present study showed significant increases in both domains of the DTI, namely flexibility in thinking and structure of knowledge in memory, as well as in the total DTI score following the SNAPPS intervention. Although the effect size (d = 0.522) was within the medium range according to Cohen's criteria, it indicates a moderate magnitude of change following the 2-week intervention. Overall, these findings suggest that the SNAPPS approach may be a useful learner-centered strategy for supporting the development of diagnostic thinking among dental students.

Ultimately, the goal of any teaching method is to promote learning and help learners achieve their educational goals. SNAPPS is a well-established and effective teaching strategy in medical education. It is a learner-centered approach that encourages active participation and provides a structured framework for learners to organize their thoughts and communicate their assessments with peers and supervisors. Furthermore, SNAPPS has been shown to improve the quality of patient care and increase learner satisfaction. Therefore, this study focused on the SNAPPS method. SNAPPS consists of six steps for presenting clinical cases: Summarize the problem, Narrow the differential diagnosis, Analyze the evidence, Probe by asking questions, Plan management, and Select a related topic for learning [12, 24, 25].

A study by Dangore-Khasbage et al. [16] on the efficacy of SNAPPS for critical thinking in dental students reported significant differences in post-test scores and clinical proficiency, indicating SNAPPS's efficacy. In their SNAPPS group, eighty percent of students agreed that the method helped enhance diagnostic confidence and narrow differential diagnoses. Students found SNAPPS helped improve their ability to distinguish between similar conditions with rationale and knowledge. Our results align with these observations, showing SNAPPS training enhanced students' flexibility in thinking and structure of knowledge in memory, which reflects improved differential diagnosis capabilities. Similar findings were reported by Seki et al. [26], who concluded SNAPPS might instill a clearer understanding of questions and uncertainties and provide greater satisfaction to residents than the OMP method. The OMP model involves five steps: get a commitment, probe for supporting evidence, teach general rules, reinforce what was done well, and correct mistakes [27]. Ramazanzade et al. compared SNAPPS and conventional clinical teaching methods on medical students' clinical reasoning skills, finding significantly higher clinical reasoning scores in the SNAPPS intervention group. They concluded SNAPPS is an effective model for fostering clinical reasoning and

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recommended its use throughout clinical teaching [14]. Although our study focused on diagnostic thinking, its demonstration of SNAPPS's positive impact on flexibility and knowledge structure aligns with Ramazanzade et al.'s findings on SNAPPS's effectiveness in improving clinical reasoning.

Owlia et al. [21] examined clinical reasoning and diagnostic thinking among dental students and reported DTI scores for overall diagnostic thinking as 136.47 ± 16.45, flexibility in thinking as 72.22 ± 11.15, and structure of knowledge in memory as 64.24 ± 7.84. In our study, pre-intervention scores were 145.45 ± 16.89 for total DTI, 76.89 ± 10.54 for flexibility, and 67.78 ± 8.77 for structure of knowledge, which were slightly higher than those reported by Owlia et al., though the differences were small.

Modi et al. [28] stated that clinical reasoning is a core competency expected of all physicians and described several teaching strategies, including SNAPPS, to encourage its acquisition. Effective teaching remarkably depends on the instructor's communication skills [29]. Students should be encouraged to clarify areas of difficulty by voicing their difficulties or questions without hesitation, improving their knowledge with additional information. Comparative findings between SNAPPS and conventional methods suggest that the multi-faceted role of the instructor and new teaching strategies contribute to enhancing the educational process, as shown in previous studies [30].

A systematic review by Xu et al. [31] examined some methods to improve diagnostic reasoning in undergraduate medical students in clinical settings. Their review included four studies, two of which used the SNAPPS technique, and reported improvements in clinical reasoning after the intervention, which aligns with our findings regarding improvement in diagnostic thinking. In a 2009 study, Wolpaw et al. [12] evaluated elements of presentation related to clinical reasoning using SNAPPS. Students using SNAPPS had two times as many differential diagnoses, justified them five times more often, and compared hypotheses more frequently. These findings suggest that SNAPPS may support diagnostic reasoning by encouraging learners to generate and justify multiple diagnostic hypotheses, which is consistent with the improvements observed in flexibility in thinking and structure of knowledge in memory in our study. Another study in 2015 assessed the generalizability of SNAPPS among Asian medical students and found the same results as the 2009 findings: SNAPPS users had more differential diagnoses and provided more evidence to support their ideas compared to a control group [32].

Wolpaw et al. also studied students' uncertainties and the use of the SNAPPS model [34]. Their analysis included 19 SNAPPS and 41 comparison presentations. Students using SNAPPS expressed uncertainty almost twice as often as the other group in all cases. Most uncertainties from SNAPPS users focused on diagnostic reasoning compared to control group students. Uncertainty about clinical findings and medications/management was not significantly different between these two groups. Educators responded with teaching aligned with these uncertainties. These findings indicate that students can help guide the educational content they receive by expressing uncertainties during case presentations, while prepared instructors can align their teaching with students' questions. These learning opportunities can be generated by students who use the SNAPPS approach [33].

Previous studies, consistent with our findings, have shown that the SNAPPS approach can produce meaningful improvements in clinical reasoning. However, addressing strong cultural norms that may hinder students' expression of uncertainty requires further investigation. Consequently, introducing the SNAPPS technique to students and instructors in medical fields may require additional strategies to foster the expression of uncertainties and initiate diagnostic and management discussions by students. Consideration should be given to forming smaller student groups during training sessions to allow greater attention to individual needs and provide more opportunities for SNAPPS practice. Instructors could receive more extensive SNAPPS training and participate in regular student briefing and practice sessions, providing more feedback and clarifying expectations. These combined student-instructor sessions could create a shared platform that emphasizes the importance of students leading each step of SNAPPS case presentations. This approach could help shift the instructor's role toward that of a facilitator and guide while reinforcing students' primary role in expressing uncertainties and selecting relevant topics for further learning. Joint training and practice for students and instructors could enhance the proper and timely implementation of SNAPPS, in which students lead case presentations and make both diagnostic thinking and uncertainties explicit [32, 34].

The findings from the previously mentioned studies highlight the importance of learner-centered educational approaches such as SNAPPS. Because the first three

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steps of the SNAPPS model (Summarize, Narrow, and Analyze) are directly related to diagnostic thinking, and because the present study demonstrated improvements in students' diagnostic thinking, learner-centered teaching methods such as SNAPPS may be valuable in medical and dental education.

One limitation of the present study was the potential Hawthorne effect, which may have been reduced by conducting the intervention in the students' natural clinical environment and minimizing direct supervision. Another important limitation was the absence of a control group, which limits the ability to attribute the observed changes solely to the SNAPPS intervention. Because the study used census sampling within a single class at one institution, the generalizability of the findings should also be interpreted with caution. Future studies involving larger samples, multiple centers, and controlled study designs are recommended.

Conclusion

The results of the present study indicate that the use of the SNAPPS model was associated with improvements in students' diagnostic thinking, including flexibility in thinking and structure of knowledge in memory. Given the predominance of traditional teaching methods in current educational settings, learner-centered approaches such as SNAPPS may help enhance the diagnostic thinking skills of dental students and could be considered as part of the dental curriculum.

Ethical considerations

This study was approved by the Zanjan University of Medical Sciences ethics committee with the approval code IR.ZUMS.REC.1401.304. Volunteer participants were fully informed about the study and its various aspects. No information that could lead to the disclosure of participants' identities was used in the reports resulting from this study, and participants' information remained confidential with the researchers. Informed consent was obtained before the start of the study.

Artificial intelligence utilization for article writing

The authors declare that no generative AI was used in the writing or editing of this manuscript.

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Conflict of interest statement

The authors declare no conflicts of interest.

Author contributions

Robab Noormohammadi contributed to the methodology and investigation of the study. Sevda Mirzazadeh contributed to the investigation. Mohammadhossein Mirsiahi contributed to writing the original draft of the manuscript. Kamyar Mansori contributed to the formal analysis. Azin Nourian contributed to the conceptualization and methodology of the study and to writing, reviewing, and editing the manuscript.

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Data availability statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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