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ORIGINAL RESEARCH

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Assessment of perceptions, attitudes, and clinical practices regarding CBCT among pediatric dentists in Türkiye: a cross-sectional questionnaire-based study

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Abstract

Background: This study aimed to evaluate the perceptions, attitudes, and clinical practices of pediatric dentists in Türkiye regarding cone-beam computed tomography (CBCT) and radiation safety guidelines. **Methods**: This cross-sectional study included 154 pediatric dentists working in Türkiye. Data were collected using a 17-item online questionnaire administered via Google Forms. The data were analyzed using IBM SPSS version 23, with the significance level set at $p < 0.05$. Pearson's chi-square test and Z-tests with Bonferroni correction were used for statistical analyses. **Results**: Among the participants, 51.9% reported using CBCT in their clinical practice, and nearly all participants supported the ALADAIP (As Low As Diagnostically Acceptable for the Individual Patient) principle. The most common indications for CBCT were pathological lesions (84.2%) and impacted teeth (73.0%), while the most influential factor guiding its use was the inadequacy of other imaging methods (93.4%). Although 79.9% of the participants had not received specific training in CBCT, the main factors limiting its use were the need to restrict CBCT to limited clinical indications (65.6%) and concerns regarding a high radiation dose (59.7%). Furthermore, familiarity with radiation safety guidelines was significantly higher among academics than among specialist trainees ($p = 0.001$). As professional experience increased, the rates of receiving CBCT-related training ($p = 0.013$) and awareness of relevant guidelines ($p = 0.001$) also increased. **Conclusions**: While CBCT offers advanced diagnostic capabilities in pediatric dentistry compared with two-dimensional radiographs, its implementation remains challenged by significant gaps in radiation safety awareness. Therefore, the early integration and standardization of comprehensive CBCT protocols within dental education curricula are critically important for promoting safe imaging practices, dose optimization, and appropriate indication selection in clinical practice.

Keywords

Cone-beam computed tomography; Pediatric dentistry; ALARA; ALADAIP

1. Introduction

In dentistry, cone-beam computed tomography (CBCT) enables the evaluation of maxillofacial structures in the axial, sagittal, and coronal planes with minimal artifacts and provides true three-dimensional visualization. In pediatric patients, this technology plays a critical role in the detection of impacted and supernumerary teeth, dentoalveolar trauma, skeletal–dental disorders, and respiratory problems. It is also used effectively in the diagnosis and follow-up of dental anomalies, including variations in the number of roots, dens in dente, and dilaceration, as well as in orthognathic surgery and implant planning, temporomandibular joint and bone pathologies, cleft lip and palate, root resorption, tooth autotransplantation, and periodontal treatment processes. However, although CBCT provides more comprehensive information than conventional imaging methods, it is also associated with a substantially higher radiation risk. In the pediatric population, ongoing organ development and cellular growth make children more susceptible than adults to the harmful effects of radiation [1]. The International Commission on Radiological Protection (ICRP) has reported that children carry a 2- to 3-fold higher radiation risk than adults [2]. In addition, a previous study reported a 24% increase in cancer incidence among 680,000 Australians exposed to computed tomography scans between the ages of 0 and 19 years, compared with non-exposed individuals [3].

This biological sensitivity, together with the risk of stochastic effects, necessitates absolute justification for the use of CBCT [4]. CBCT should be performed only when low-dose imaging techniques, such as periapical and panoramic radiography, are insufficient, and it should be acquired using the narrowest possible field of view (FOV) [5]. Therefore, the

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use of CBCT in pediatric dentistry requires strict adherence not only to the ALARA principle (As Low As Reasonably Achievable), which balances diagnostic benefit against radiation risk, but also to the ALADA principle (As Low As Diagnostically Acceptable), which aims to preserve clinical image quality while reducing radiation dose, and the ALADAIP protocol (As Low As Diagnostically Acceptable for the Individual Patient), which advocates patient -specific optimization [6].

With the increasing use of CBCT, evidence-based SEDENTEXCT (Safety and Efficacy of a New and Emerging Dental X-ray Modality) and DIMITRA (Dentomaxillofacial Paediatric Imaging: An Investigation Towards Low-Dose Radiation Induced Risks) guidelines have been developed to standardize imaging indications and optimize radiation protection. While SEDENTEXCT provides general recommendations for pediatric patients, the DIMITRA project specifically focuses on optimizing exposure in children and adolescents by advocating stricter justification criteria and individualized protocols tailored to pediatric dental imaging [7, 8]. Similarly, the ICRP emphasizes the need for patient-specific exposure adjustment, collimation, and appropriate FOV selection [2]. Although CBCT use in pediatric dentistry has been increasing, a significant gap remains in the literature regarding how often this technology is preferred in children under the age of 15 years, as well as the required exposure parameters and specific clinical indications. Therefore, this study aimed to evaluate the perceptions, attitudes, and clinical practices of pediatric dentists working in Türkiye regarding cone-beam computed tomography (CBCT) technology and pediatric radiation safety guidelines.

2. Materials and methods

2.1 Study design and sample selection

This cross-sectional, descriptive, questionnaire-based study aimed to evaluate the knowledge levels, attitudes, and clinical practice habits of pediatric dentists working in Türkiye regarding CBCT and radiation safety. The questionnaire was conducted between December 2025 and March 2026. To ensure sample homogeneity, specific eligibility criteria were established. The inclusion criteria were: (1) being an actively practicing pediatric dentist (academician or specialist) or a postgraduate specialty resident/doctoral student currently training in Türkiye, and (2) voluntarily providing informed consent to participate. Conversely, the exclusion criteria comprised: (1) general dental practitioners or specialists from other dental disciplines, and (2) individuals who declined to participate or submitted incomplete questionnaires. Participation was entirely voluntary, and participants were allowed to complete the questionnaire only once during the data collection period. No personally identifiable information was collected.

The sample size was calculated using G*Power software (version 3.1, Heinrich-Heine-University Düsseldorf, Düsseldorf, NRW, Germany). Based on the reference study by Giray *et al*. [9], the effect size for the chi-square test was determined as $w = 0.265$, which represents Cohen's w derived from the cross-tabulation of pediatric dentists' knowledge and demographic characteristics. Using this effect size, power analysis was performed with 95% confidence ($1 - \alpha = 0.95$) and 80% statistical power ($1 - \beta = 0.80$), and the minimum required sample size was calculated as 138 participants. The study included a total of 154 participants, comprising 129 women and 25 men. A *post hoc* power analysis performed after completion of the study showed that the test power was 84.6% ($1 - \beta = 0.846$).

2.2 Data collection instrument and questionnaire structure

A 17-item multiple-choice questionnaire, developed based on the relevant literature [4, 10–12], was used as the data collection tool. The questionnaire consisted of three main sections:

1. Demographic data: Participants' sex, specialty level, including academician, specialist, and specialty resident, and duration of professional experience.
2. CBCT knowledge level and radiation safety: Familiarity with radiation dose protocols, including FOV settings and the effects of voxel size, as well as current radiation safety guidelines, including AAE & AAOMR (American Association of Endodontists and American Academy of Oral and Maxillofacial Radiology), SEDENTEXCT, and related guidelines.
3. Clinical practices and attitudes: Frequency of CBCT use, reasons for preference, specific indications, and factors limiting its use.

To ensure the content validity of the data collection instrument, the preliminary draft of the questionnaire was reviewed and evaluated by expert pediatric dentists and dentomaxillofacial radiologists. These experts assessed each item in terms of clarity, clinical relevance, and adequacy for measuring CBCT-related knowledge and attitudes. Based on their feedback and consensus, minor modifications were made to finalize the 17-item questionnaire prior to its distribution. Subsequently, to establish the reliability and comprehensibility of the instrument, a pilot study was conducted with a small cohort of pediatric dentists (n = 10) who confirmed that the questions were clear and unambiguous; these pilot respondents were excluded from the final study sample. The full questionnaire is available as **Supplementary material**.

2.3 Implementation and data collection process

Participants were recruited nationwide using an institutional pathway. The questionnaire was converted into a digital format using Google Forms and distributed to participants through email and online communication channels, including Instagram and WhatsApp. To ensure data privacy and ethical compliance, the survey link was officially forwarded to national pediatric dentistry associations, which disseminated it directly to their registered members via official mailing lists and communication networks. Consequently, the authors did not have direct access to the personal contact information of the participants. To maximize the response rate and minimize non-response bias, follow-up reminder messages were sent through the same communication channels at two and four weeks after the initial distribution. To ensure the uniqueness of responses, the form required participants to log in with a Google account, and each participant was permitted to submit

only one response. At the beginning of the questionnaire, participants were informed about the aim of the study, and written informed consent was obtained, and all data were collected anonymously.

2.4 Statistical analysis

The data were analyzed using IBM SPSS Statistics version 23.0 (IBM Corp., Armonk, NY, USA). Descriptive statistics for categorical variables were presented as frequencies (n) and percentages (%). Pearson's chi-square test was used to examine the relationships between variables. For statistically significant comparisons, the *Z*-test with Bonferroni correction was used for multiple comparisons to identify which group contributed to the observed difference. A p-value of < 0.05 was considered statistically significant in all analyses.

3. Results

3.1 Demographic data and professional profile

Among the participants, 83.8% were women and 16.2% were men. According to professional status, 52.0%, 24.0%, and 24.0% of the participants were specialty residents, specialist dentists, and academicians, respectively. The duration of clinical experience was <5 years, 5–10 years, 10–15 years, and >15 years in 65.6%, 13.6%, 10.4%, and 10.4% of the participants, respectively (Table 1). No statistically significant association was found between sex and any of the investigated parameters ($p > 0.05$).

TABLE 1. Descriptive statistics of variables.

Variables	Frequency	Percentage
Sex		
Female	129	83.8
Male	25	16.2
Specialty level in the field		
Specialty/PhD student	80	52
Specialist dentist	37	24
Faculty member	37	24
Clinical experience		
<5 yr	101	65.6
5–10 yr	21	13.6
10–15 yr	16	10.4
>15 yr	16	10.4

3.2 CBCT knowledge level and radiation safety attitudes

Among the participants, 83.7% considered it a fundamental requirement that diagnostic benefit should take precedence over radiation dose when imaging children. Nearly half of the participants (49.4%) were not familiar with any current radiation safety guidelines. Among those who reported familiarity with existing recommendations, 35.1% were aware of the AAE & AAOMR recommendations, 22.7% of national guidelines, and 5.8% of the SEDENTEXCT guidelines. Regarding dose reduction in pediatric patients, 55.8% of the participants knew that a smaller FOV should be preferred, and 56.5% were aware that image resolution and radiation dose increase as voxel size decreases. Furthermore, 40.3% of the participants knew that there is no "absolutely safe" effective dose threshold with respect to stochastic effects, whereas 46.8% reported having no knowledge of this issue. Notably, 79.9% of the participants stated that they had not received any prior specialized training in CBCT. Nearly all participants (98.7%) believed that the ALADAIP principle should be applied in pediatric dentistry (Table 2).

3.3 Clinical practice patterns and indications

Of the participants, 51.9% actively used CBCT in pediatric patients. The most frequently reported reason for preferring CBCT was its superior diagnostic capability compared with two-dimensional radiographs (55.2%). In addition, 65.6% of the participants stated that they restricted the use of CBCT because of its limited indications, whereas 59.7% reported reluctance to use it because of concerns regarding the high radiation dose. When requesting CBCT examinations, the most influential factor was the inadequacy of other imaging methods, as reported by 93.4% of the participants. In pediatric dentistry, CBCT was most frequently preferred for the evaluation of pathological lesions (84.2%), impacted or supernumerary teeth (73.0%), and dental trauma (53.9%). The most common age group for CBCT requests was 10–15 years (41.4%) (Table 2).

3.4 Effect of academic status and clinical experience

Academic title had a significant effect on the knowledge level of the participants. For instance, 27.0% of academicians and 57.5% of specialty residents were not familiar with CBCT guidelines ($p = 0.001$). A significantly higher proportion of academicians (78.4%) correctly knew that FOV optimization should be used to reduce radiation dose compared with specialty residents (51.2%) and specialist dentists (43.2%) ($p = 0.005$). Moreover, a significantly lower proportion of specialist dentists (32.4%) correctly knew that image resolution and radiation dose increase as voxel size decreases, compared with academicians (67.6%) ($p = 0.002$) (Table 3).

As the duration of experience increased, the rate of receiving training ($p = 0.013$) and awareness of guidelines ($p = 0.001$) also increased. Among the participants, 43.8% of physicians with >15 years of experience had received training, compared to 14.9% of those with <5 years of experience. Furthermore, the approach of "I request CBCT at any age if indicated" was significantly more prevalent among experienced physicians (50%) compared to beginners (12.1%) ($p = 0.007$) (Table 4).

TABLE 2. Descriptive statistics related to the questions.

Questionnaire items and responses	Frequency	Percentage
When considering CBCT imaging in pediatric patients, is it a fundamental requirement that the diagnostic benefit obtained should outweigh the radiation dose to which the patient will be exposed?		
Yes	128	83.7
No	25	16.3
Which guidelines/recommendations are you familiar with?		
National Guidelines	35	22.7
AAE & AAOMR	54	35.1
SEDENTEXC	9	5.8
None	76	49.4
When performing CBCT imaging in pediatric patients, which primary protocol setting should be preferred compared with adult patients to reduce radiation dose?		
Smaller FOV	86	55.8
Larger FOV	11	7.1
I do not know	57	37.1
What is the main consequence of voxel size selection in CBCT images obtained from children?		
As voxel size decreases, image resolution and radiation dose increase	87	56.5
As voxel size increases, image resolution and radiation dose increase	15	9.7
I do not know	52	33.8
In CBCT indications for children, is there an effective dose threshold that can be considered “absolutely safe” in terms of stochastic effects?		
Yes	20	13.0
No	62	40.3
I do not know	72	46.8
Have you previously received training on CBCT imaging and/or interpretation for the dentomaxillofacial region?		
Yes	31	20.1
No	123	79.9
Do you use CBCT imaging in pediatric patients?		
Yes	80	51.9
No	74	48.1
As a pediatric dentist, what are the reasons that limit your indications for CBCT?		
Conventional two-dimensional imaging methods are sufficient	69	44.8
Lack of knowledge about CBCT	73	47.4
I do not prefer it because of the high radiation dose	92	59.7
Limited indications/I do not consider it necessary in most cases	101	65.6
High cost/It is expensive	52	33.8
Lack of the necessary equipment in my institution	27	17.5
It is difficult to use and interpret	55	35.7
For what reason do you most commonly prefer CBCT as an imaging method?		
CBCT is a better diagnostic tool than two-dimensional radiographs	85	55.2
It facilitates measurement and image evaluation	24	15.6
CBCT takes less time than conventional CT	4	2.6
I do not prefer it	41	26.6

TABLE 2. Continued.

Questionnaire items and responses	Frequency	Percentage
Which factors do you consider when deciding to request CBCT in pediatric patients?		
Other imaging methods being insufficient for diagnosis and treatment	142	93.4
Clinical diagnosis	101	66.4
Patient age	65	42.8
Previous radiation exposure	39	25.7
Level of cooperation	58	38.2
Growth potential and developmental stage	45	29.6
What age range do you most frequently prescribe CBCT in pediatric patients?		
5–10 yr	36	23.7
10–15 yr	63	41.4
I request it at any age if indicated	34	22.4
I have never requested it	55	36.2
As a pediatric dentist, what are the most common/critical indications for prescribing CBCT in pediatric patients?		
Dental anomalies	64	42.1
Impacted and supernumerary teeth	111	73.0
Dental trauma	82	53.9
Pathological lesions	128	84.2
Syndromic patients	46	30.3
Orthodontic planning	19	12.5
Endodontic treatments	23	15.1
Suspicion of root fracture	60	39.5
Planning implant treatment in young individuals	25	16.4
Diagnosis of caries and/or periapical lesions	10	6.6
Do you think the ALADAIP principle should be applied in pediatric dentistry?		
Yes	152	98.7
No	2	1.3

AAE & AAOMR: Association of Endodontists & American Academy of Oral and Maxillofacial Radiology; ALADAIP: As Low As Diagnostically Acceptable for the Individual Patient; CBCT: cone-beam computed tomography; CT: computed tomography; FOV: field of view; SEDENTEXC: Safety and Efficacy of a New and Emerging Dental X-ray Modality.

TABLE 3. Examination of the association between specialty levels in the field and categorical variables.

Questionnaire & Response	Specialty Level in the Field			Total	Test Statistic	p^x
	Specialty/PhD Student	Specialist Dentist	Faculty Member			
When considering CBCT imaging in pediatric patients, is it a fundamental requirement that the diagnostic benefit obtained should outweigh the radiation dose to which the patient will be exposed?						
Yes	60 (75.9)^a	33 (89.2)^{a,b}	35 (94.6)^b	128 (83.7)	7.500	**0.024**
No	19 (24.1)	4 (10.8)	2 (5.4)	25 (16.3)		
Which guidelines/recommendations are you familiar with?*						
National Guidelines	14 (17.5)	9 (24.3)	12 (32.4)	35 (22.7)	26.253	**0.001**
AAE & AAOMR	24 (30.0)	13 (35.1)	17 (45.9)	54 (35.1)		
SEDENTEXC	1 (1.3)^a	2 (5.4)^{a,b}	6 (16.2)^b	9 (5.8)		
None	46 (57.5)^a	20 (54.1)^{a,b}	10 (27.0)^b	76 (49.4)		

TABLE 3. Continued.

Questionnaire & Response	Specialty Level in the Field			Total	Test Statistic	p^x
	Specialty/PhD Student	Specialist Dentist	Faculty Member			
When performing CBCT imaging in pediatric patients, which primary protocol setting should be preferred compared with adult patients to reduce radiation dose?						
Smaller FOV	41 (51.2)^a	16 (43.2)^a	29 (78.4)^b	86 (55.8)		
Larger FOV	7 (8.8)	1 (2.7)	3 (8.1)	11 (7.1)	14.694	**0.005**
I do not know	32 (40.0)^a	20 (54.1)^a	5 (13.5)^b	57 (37.0)		
What is the main consequence of voxel size selection in CBCT images obtained from children?						
As voxel size decreases, image resolution and radiation dose increase	50 (62.5)^a	12 (32.4)^b	25 (67.6)^a	87 (56.5)	17.060	**0.002**
As voxel size increases, image resolution and radiation dose increase	5 (6.3)	4 (10.8)	6 (16.2)	15 (9.7)		
I do not know	25 (31.3)^a	21 (56.8)^b	6 (16.2)^a	52 (33.8)		
In CBCT indications for children, is there an effective dose threshold that can be considered “absolutely safe” in terms of stochastic effects?						
Yes	7 (8.8)	7 (18.9)	6 (16.2)	20 (13.0)		
No	27 (33.8)	14 (37.8)	21 (56.8)	62 (40.3)	10.956	**0.027**
I do not know	46 (57.5)^a	16 (43.2)^{a,b}	10 (27.0)^b	72 (46.8)		
Have you previously received training on CBCT imaging and/or interpretation for the dentomaxillofacial region?						
Yes	14 (17.5)	6 (16.2)	11 (29.7)	31 (20.1)	2.817	0.244
No	66 (82.5)	31 (83.8)	26 (70.3)	123 (79.9)		
Do you use CBCT imaging in pediatric patients?						
Yes	33 (41.3)^a	19 (51.4)^{a,b}	28 (75.7)^a	80 (51.9)	12.018	**0.002**
No	47 (58.8)	18 (48.6)	9 (24.3)	74 (48.1)		
As a pediatric dentist, what are the reasons that limit your indications for CBCT?*						
Conventional two-dimensional imaging methods are sufficient	35 (43.8)	16 (43.2)	18 (48.6)	69 (44.8)		
Lack of knowledge about CBCT	43 (53.8)	15 (40.5)	15 (40.5)	73 (47.4)		
I do not prefer it because of the high radiation dose	40 (50.0)^a	23 (62.2)^{a,b}	29 (78.4)^b	92 (59.7)	31.452	**0.005**
Limited indications/I do not consider it necessary in most cases	51 (63.7)	22 (59.5)	28 (75.7)	101 (65.6)		
High cost/It is expensive	30 (37.5)	13 (35.1)	9 (24.3)	52 (33.8)		
Lack of the necessary equipment in my institution	18 (22.5)^a	8 (21.6)^a	1 (2.7)^b	27 (17.5)		
It is difficult to use and interpret	37 (46.3)	9 (24.3)	9 (24.3)	55 (35.7)		

TABLE 3. Continued.

Questionnaire & Response	Specialty Level in the Field			Total	Test Statistic	p^x
	Specialty/PhD Student	Specialist Dentist	Faculty Member			
For what reason do you most commonly prefer CBCT as an imaging method?						
CBCT is a better diagnostic tool than two-dimensional radiographs	45 (56.3)	19 (51.4)	21 (56.8)	85 (55.2)	18.071	**0.006**
It facilitates measurement and image evaluation	8 (10.0)^{a}	4 (10.8)^{a,b}	12 (32.4)^{b}	24 (15.6)		
CBCT takes less time than conventional CT	4 (5.0)	0 (0.0)	0 (0.0)	4 (2.6)		
I do not prefer it	23 (28.7)^{a,b}	14 (37.8)^{a}	4 (10.8)^{b}	41 (26.6)		
Which factors do you consider when deciding to request CBCT in pediatric patients?*						
Other imaging methods being insufficient for diagnosis and treatment	73 (92.4)	32 (88.9)	37 (100.0)	142 (93.4)	11.964	0.449
Clinical diagnosis	57 (72.2)	24 (66.7)	20 (54.1)	101 (66.4)		
Patient age	31 (39.2)	18 (50.0)	16 (43.2)	65 (42.8)		
Previous radiation exposure	21 (26.6)	8 (22.2)	10 (27.0)	39 (25.7)		
Level of cooperation	27 (34.2)	13 (36.1)	18 (48.6)	58 (38.2)		
Growth potential and developmental stage	24 (30.4)	9 (25.0)	12 (32.4)	45 (29.6)		
At what age range did you most frequently prescribe CBCT in pediatric patients?*						
5–10 yr	19 (24.1)	11 (30.6)	6 (16.2)	36 (23.7)	34.915	<**0.001**
10–15 yr	33 (41.8)	15 (41.7)	15 (40.5)	63 (41.4)		
I request it at any age if indicated	8 (10.1)^{a}	7 (19.4)^{a}	19 (51.4)^{b}	34 (22.4)		
I have never requested it	36 (45.6)	12 (33.3)	7 (18.9)	55 (36.2)		
As a pediatric dentist, what are the most common/critical indications for prescribing CBCT in pediatric patients?*						
Dental anomalies	35 (44.3)	13 (36.1)	16 (43.2)	64 (42.1)	24.951	0.203
Impacted and supernumerary teeth	61 (77.2)	21 (58.3)	29 (78.4)	111 (73.0)		
Dental trauma	41 (51.9)	16 (44.4)	25 (67.6)	82 (53.9)		
Pathological lesions	68 (86.1)	30 (83.3)	30 (81.1)	128 (84.2)		
Syndromic patients	28 (35.4)	7 (19.4)	11 (29.7)	46 (30.3)		
Orthodontic planning	11 (13.9)	3 (8.3)	5 (13.5)	19 (12.5)		
Endodontic treatments	18 (22.8)	2 (5.6)	3 (8.1)	23 (15.1)		
Suspicion of root fracture	33 (41.8)	12 (33.3)	15 (40.5)	60 (39.5)		
Planning implant treatment in young individuals	15 (19.0)	4 (11.1)	6 (16.2)	25 (16.4)		
Diagnosis of caries and/or periapical lesions	6 (7.6)	1 (2.8)	3 (8.1)	10 (6.6)		
Do you think the ALADAIP principle should be applied in pediatric dentistry?						
Yes	78 (97.5)	37 (100.0)	37 (100.0)	152 (98.7)	1.874	0.392
No	2 (2.5)	0 (0.0)	0 (0.0)	2 (1.3)		

*^{x}Pearson's chi-square; frequency (percentage); ^{a,b}: No difference between groups sharing the same letter. *Multiple responses. AAE & AAOMR: American Association of Endodontists & American Academy of Oral and Maxillofacial Radiology; ALADAIP: As Low As Diagnostically Acceptable for the Individual Patient; CBCT: cone-beam computed tomography; CT: computed tomography; FOV: field of view; SEDENTEXC: Safety and Efficacy of a New and Emerging Dental X-ray Modality. Bold values indicate statistical significance ($p < 0.05$).*

TABLE 4. Examination of the association between clinical experience and categorical variables.

Questionnaire item & Response	Clinical experience				Total	Test Statistic	p^x
	<5 yr	5–10 yr	10–15 yr	>15 yr			
When considering CBCT imaging in pediatric patients, is it a fundamental requirement that the diagnostic benefit obtained should be more important than the radiation dose to which the patient will be exposed?							
Yes	80 (80.0)	18 (85.7)	15 (93.8)	15 (93.8)	128 (83.7)	3.428	0.330
No	20 (20.0)	3 (14.3)	1 (6.3)	1 (6.3)	25 (16.3)		
Which guidelines/recommendations are you familiar with?*							
National Guidelines	22 (21.8)	6 (28.6)	2 (12.5)	5 (31.3)	35 (22.7)		
AAE & AAOMR	33 (32.7)	10 (47.6)	8 (50.0)	3 (18.8)	54 (35.1)	34.455	**0.001**
SEDENTEXC	2 (2.0)^{a}	2 (9.5)^{a,b}	0 (0.0)	5 (31.3)^{b}	9 (5.8)		
None	55 (54.5)	8 (38.1)	8 (50.0)	5 (31.3)	76 (49.4)		
When performing CBCT imaging in pediatric patients, what is the primary protocol setting that should be preferred over that of adult patients to reduce radiation dose?							
Smaller FOV	52 (51.5)	14 (66.7)	10 (62.5)	10 (62.5)	86 (55.8)		
Larger FOV	8 (7.9)	0 (0.0)	3 (18.8)	0 (0.0)	11 (7.1)	8.654	0.194
I do not know	41 (40.6)	7 (33.3)	3 (18.8)	6 (37.5)	57 (37.0)		
What is the main consequence of voxel size selection in CBCT images obtained from children?							
As voxel size decreases, image resolution and radiation dose increase	59 (58.4)	12 (57.1)	9 (56.3)	7 (43.8)	87 (56.5)	3.168	0.787
As voxel size increases, image resolution and radiation dose increase	8 (7.9)	2 (9.5)	3 (18.8)	2 (12.5)	15 (9.7)		
I do not know	34 (33.7)	7 (33.3)	4 (25.0)	7 (43.8)	52 (33.8)		
In CBCT indications for children, is there an effective dose threshold that can be considered “absolutely safe” in terms of stochastic effects?							
Yes	11 (10.9)	1 (4.8)	5 (31.3)	3 (18.8)	20 (13.0)		
No	37 (36.6)^{a}	15 (71.4)^{b}	3 (18.8)^{a}	7 (43.8)^{a,b}	62 (40.3)	16.639	**0.011**
I do not know	53 (52.5)	5 (23.8)	8 (50.0)	6 (37.5)	72 (46.8)		
Have you previously received training on CBCT imaging and/or interpretation for the dentomaxillofacial region?							
Yes	15 (14.9)^{a}	3 (14.3)^{a,b}	6 (37.5)^{a,b}	7 (43.8)^{b}	31 (20.1)	10.751	**0.013**
No	86 (85.1)	18 (85.7)	10 (62.5)	9 (56.3)	123 (79.9)		
Do you use CBCT imaging in pediatric patients?							
Yes	46 (45.5)	12 (57.1)	11 (68.8)	11 (68.8)	80 (51.9)	5.505	0.138
No	55 (54.5)	9 (42.9)	5 (31.3)	5 (31.3)	74 (48.1)		
As a pediatric dentist, what are the reasons that limit your indications for CBCT?*							
Conventional two-dimensional imaging methods are sufficient	44 (43.6)	11 (52.4)	6 (37.5)	8 (50.0)	69 (44.8)		
Lack of knowledge about CBCT	51 (50.5)	11 (52.4)	4 (25.0)	7 (43.8)	73 (47.4)		
I do not prefer it because of the high radiation dose	52 (51.5)^{a}	18 (85.7)^{b}	13 (81.3)^{a,b}	9 (56.3)^{a,b}	92 (59.7)	34.354	**0.033**
Limited indications/I do not consider it necessary in most cases	68 (67.3)	15 (71.4)	11 (68.8)	7 (43.8)	101 (65.6)		
High cost/It is expensive	37 (36.6)	3 (14.3)	4 (25.0)	8 (50.0)	52 (33.8)		
Lack of the necessary equipment in my institution	20 (19.8)	3 (14.3)	2 (12.5)	2 (12.5)	27 (17.5)		
It is difficult to use and interpret	42 (41.6)	7 (33.3)	4 (25.0)	2 (12.5)	55 (35.7)		

TABLE 4. Continued.

Questionnaire item & Response	Clinical experience				Total	Test Statistic	p^x
	<5 yr	5–10 yr	10–15 yr	>15 yr			
For what reason do you most commonly prefer CBCT as an imaging method?							
CBCT is a better diagnostic tool than two-dimensional radiographs	57 (56.4)	14 (66.7)	7 (43.8)	7 (43.8)	85 (55.2)	10.527	0.310
It facilitates measurement and image evaluation	11 (10.9)	3 (14.3)	5 (31.3)	5 (31.3)	24 (15.6)		
CBCT takes less time than conventional CT	4 (4.0)	0 (0.0)	0 (0.0)	0 (0.0)	4 (2.6)		
I do not prefer it	29 (28.7)	4 (19.0)	4 (25.0)	4 (25.0)	41 (26.6)		
Which factors do you consider when deciding to request CBCT in pediatric patients?*							
Other imaging methods being insufficient for diagnosis and treatment	92 (92.9)	21 (100.0)	14 (87.5)	15 (93.8)	142 (93.4)	18.960	0.394
Clinical diagnosis	67 (67.7)	15 (71.4)	11 (68.8)	8 (50.0)	101 (66.4)		
Patient age	36 (36.4)	13 (61.9)	9 (56.3)	7 (43.8)	65 (42.8)		
Previous radiation exposure	25 (25.3)	6 (28.6)	6 (37.5)	2 (12.5)	39 (25.7)		
Level of cooperation	32 (32.3)	10 (47.6)	9 (56.3)	7 (43.8)	58 (38.2)		
Growth potential and developmental stage	28 (28.3)	7 (33.3)	4 (25.0)	6 (37.5)	45 (29.6)		
At what age range did you most frequently prescribe CBCT in pediatric patients?*							
5–10 yr	25 (25.3)	4 (19.0)	4 (25.0)	3 (18.8)	36 (23.7)	27.285	**0.007**
10–15 yr	43 (43.4)	8 (38.1)	7 (43.8)	5 (31.3)	63 (41.4)		
I request it at any age if indicated	12 (12.1)^{a}	6 (28.6)^{a,b}	8 (50.0)^{b}	8 (50.0)^{b,c}	34 (22.4)		
I have never requested it	42 (42.4)	6 (28.6)	3 (18.8)	4 (25.0)	55 (36.2)		
As a pediatric dentist, what are the most common/critical indications for prescribing CBCT in pediatric patients?*							
Dental anomalies	43 (43.4)	10 (47.6)	5 (31.3)	6 (37.5)	64 (42.1)	20.578	0.901
Impacted and supernumerary teeth	75 (75.8)	15 (71.4)	10 (62.5)	11 (68.8)	111 (73.0)		
Dental trauma	51 (51.5)	10 (47.6)	11 (68.8)	10 (62.5)	82 (53.9)		
Pathological lesions	84 (84.8)	18 (85.7)	15 (93.8)	11 (68.8)	128 (84.2)		
Syndromic patients	30 (30.3)	5 (23.8)	4 (25.0)	7 (43.8)	46 (30.3)		
Orthodontic planning	12 (12.1)	4 (19.0)	2 (12.5)	1 (6.3)	19 (12.5)		
Endodontic treatments	19 (19.2)	2 (9.5)	2 (12.5)	1 (6.3)	23 (15.1)		
Suspicion of root fracture	42 (42.4)	8 (38.1)	5 (31.3)	5 (31.3)	60 (39.5)		
Planning implant treatment in young individuals	17 (17.2)	4 (19.0)	2 (12.5)	2 (12.5)	25 (16.4)		
Diagnosis of caries and/or periapical lesions	7 (7.1)	2 (9.5)	1 (6.3)	1 (0.0)	10 (6.6)		
Do you think the ALADAIP principle should be applied in pediatric dentistry?							
Yes	99 (98)	21 (100)	16 (100)	16 (100)	152 (98.7)	1.063	0.786
No	2 (2)	0 (0)	0 (0)	0 (0)	2 (1.3)		

*^{x}Pearson's chi-square; frequency (percentage); $^{a–c}$: No difference between groups with the same letter; *Multiple response. AAE & AAOMR: American Association of Endodontists & American Academy of Oral and Maxillofacial Radiology; ALADAIP: As Low As Diagnostically Acceptable for the Individual Patient; CBCT: cone-beam computed tomography; CT: computed tomography; FOV: field of view; SEDENTEXC: Safety and Efficacy of a New and Emerging Dental X-ray Modality. Bold values indicate statistical significance ($p < 0.05$).*

4. Discussion

The rates of CBCT use, indication preferences, and awareness of radiation safety protocols among pediatric dentists demonstrate both similarities and notable variations when compared with findings in current literature. Parveen *et al.* [12] reported that 74.4% of orthodontists considered the risk–benefit balance before requesting CBCT. In contrast, 83.7% of the pediatric dentists in the present study stated that, in pediatric patients, diagnostic benefit should take precedence over radiation dose as a fundamental requirement. The literature also reveals marked differences in awareness of CBCT and radiation safety guidelines. Uvarichev *et al*. [11] found that although 70% of Russian dentists were aware of national health regulations and radiation protection standards, they were largely unfamiliar with CBCT-specific guidelines (24.7%). Almohaimede *et al*. [13] reported that 34% of dentists in Saudi Arabia were familiar with the recommendations of the National Council on Radiation Protection (NCRP) and the ICRP. In the present study, 49.4% of pediatric dentists were unfamiliar with any current radiation safety guidelines, which is comparable to the 49% guideline awareness rate reported by Parveen *et al.* [12] in orthodontics. These discrepancies may be attributed to the inadequate translation of current international guidelines into local languages, variations in institutional training curricula, and the lack of standardized radiation safety education in postgraduate training. Furthermore, the absence of standardized education creates an important gap between the conceptual acceptance of radiation safety and its actual application in daily practice. Although a striking 98.7% of the participants in the present study supported the pediatric-specific ALADAIP principle in theory, nearly half of them (49.4%) were unfamiliar with current radiation safety guidelines. This finding indicates that although pediatric dentists may recognize the clinical importance of patient-specific dose optimization, many may still lack the practical, guideline-based knowledge required for its consistent implementation. Ultimately, this gap underscores that theoretical endorsement alone does not ensure safe clinical practice without direct familiarity with standardized protocols.

One of the striking findings of the present study was that nearly all participants (98.7%) endorsed the application of the ALADAIP principle in pediatric dentistry. Previously, Uvarichev *et al*. [11] reported critically low rates of awareness of the ALARA (19%) and ALADA (12%) principles among Russian dentists, whereas Parveen *et al*. [12] reported awareness levels of 53.5% for ALARA and 28.9% for ALADA among orthodontists. The high awareness rate observed in the present study may be associated with the large proportion of academicians (24.0%) and specialty residents (52.0%) in our cohort, as these groups may more closely follow current radiology protocols. However, the discrepancy between this high stated awareness and the fact that 79.9% of participants had not received any specialized CBCT training requires methodological interpretation. Because these principles were presented as predefined response options in the questionnaire, participants may have selected them based on recognition rather than detailed technical knowledge of the terms. Chinna *et al*. [14] reported similar findings, highlighting insufficient knowledge regarding the use of CBCT among Indian dental practitioners and describing this as a "theoretical–practical mismatch".

The significantly higher level of knowledge among academicians compared with specialty residents ($p = 0.001$) suggests that theoretical awareness may be related to academic status and greater engagement with literature. In a questionnaire-based study conducted by Abdalla-Aslan *et al*. [15] among specialist dentists in Israel, 70.3% of dentists answered radiation dose-related questions correctly, and the CBCT training rate was 61.2%, whereas in the present study, this rate remained limited to 20.1%. In addition, Mizban *et al*. [16] evaluated CBCT use in a pediatric dentistry department at a London hospital and reported 94% compliance with SEDENTEXCT guidelines, which increased to 100% after staff training. CBCT findings also led to modifications in 44% of treatment plans, highlighting its significant impact on clinical decision-making. These findings confirm the need for CBCT-specific educational modules in pediatric dentistry specialty training in Türkiye.

Uvarichev *et al*. [11] reported that 54.4% of dentists believed that there was a "completely harmless" radiation dose for CBCT examinations. In the present study, although only 13.0% of participants believed that an "absolutely safe" effective dose threshold exists, 46.8% stated that they did not know, indicating persistent uncertainty regarding stochastic radiation risk. This erroneous perception, or lack of knowledge, regarding a "safe dose" contradicts the Linear No-Threshold model, which maintains that there is no lower threshold for stochastic radiation effects, and further emphasizes the vital importance of dose optimization through ALADAIP in pediatric patients. This finding is consistent with the results reported by Lavanya *et al*. [17] in a study of dentists in India, in which most participants were found to lack knowledge about radiation doses and imaging characteristics.

Altoukhi *et al*. [18], who examined the biological effects of radiation on pediatric tissues, found that CBCT examinations caused transient genotoxic and cytotoxic changes in buccal mucosal cells. The finding that these cellular alterations were directly influenced by the specific exposure parameters of the CBCT protocol supports the importance of proper dose optimization and targeted FOV selection in minimizing biological risk in pediatric patients. Optimization of FOV and voxel size in CBCT is critical for minimizing radiation dose in pediatric patients. Parveen *et al*. [12] reported that 35.8% of their cohort knew FOV selection. In the present study, the proportion of participants who knew that a smaller FOV should be preferred was 55.8%, while 56.5% were aware of the voxel–dose relationship. As reported by Albayrak and Özdemir [19], more frequent use of CBCT by radiologists improves the accuracy of technical parameter selection ($p < 0.001$). Similarly, in the present study, academicians had significantly higher levels of knowledge regarding FOV optimization (78.4%) and the voxel–dose relationship (67.6%) than the other groups. Although smaller voxel sizes produce sharper images, reducing the FOV according to the anatomical region of interest remains an indispensable requirement for dose safety in pediatric patients. In a retrospective analysis by Mortazavi *et al*. [20], 100% success was observed in FOV selection under specific clinical conditions, such as

trauma and cleft palate; however, the variations observed in routine pediatric cases, such as impacted teeth, are noteworthy. This finding supports the view that the ALADAIP principle endorsed by the pediatric dentists in our study has not yet been fully standardized in clinical practice and that radiation safety training should be revised with a practical focus on FOV optimization.

Regarding the integration of this technology into pediatric practice, the active CBCT use rate of 51.9% in the present study indicates that CBCT has gained considerable momentum in pediatric dentistry compared with the lower rates reported by Yalda *et al*. [21] (8%) and Alzamzami *et al.* [22] (9.2%). Akleyin *et al*. [23] also emphasized that CBCT use in pediatric dentistry has increased significantly over the past 10 years ($p < 0.05$; $r = 0.608$). In the present study, the most common age range for CBCT prescription was 10–15 years (41.4%), which is consistent with the mean ages of 11.06 years reported by Ertuğrul and Apaydın [24] and 13.42 years reported by Mortazavi *et al*. [20]. Similarly, Akleyin *et al*. [23] found that, in Türkiye, CBCT requests among patients under 18 years of age over 10 years were concentrated predominantly in the 12–17-year age group, which accounted for 71.77% of all requests. Taken together, these findings suggest that CBCT is increasingly preferred in pediatric practice as an important diagnostic tool, particularly for surgical and pathological conditions encountered during the mixed and permanent dentition periods.

Among the reasons for CBCT use, pathological lesions (84.2%) and impacted teeth (73.0%) were the most frequently reported indications in our study. The responses of the pediatric dentists in the present study regarding CBCT indications were consistent with the clinical data reported in previous studies. For instance, Mortazavi *et al*. [20] reported that the most common indication for CBCT in patients under 18 years of age was tooth impaction, particularly canine impaction (48.2%), followed by pathological lesions (19.6%). This indication profile in pediatric dentistry mainly reflects the need for complex surgical and developmental assessment, in contrast to implant planning, which is often the primary indication in general surgical dental specialties. In addition, Van Acker *et al*. [25] reported that CBCT examinations in pediatric patients were most frequently prescribed for developing dentition-related conditions (40%), followed by other indications (18%), surgical reasons (16%), dentoalveolar trauma (14%), endodontic conditions (10%), periodontal indications (1%), and TMJ assessment (1%). In a Turkish pediatric population, Gümrü *et al*. [26] found that children under 14 years of age accounted for 5% of all CBCT examinations. In that study, the maxillary canine region was the most frequently investigated area (85.5%), and the most common indications were impacted teeth (41.4%), bone pathologies (31.0%), dental anomalies (29.6%), and orofacial clefts or syndromes (11.6%). Indeed, in the study by Abdalla-Aslan *et al*. [15], implant planning (27%) was the leading indication among specialist dentists, whereas in pediatric dentistry, CBCT use is more closely associated with the diagnosis of complex developmental anomalies and the localization of impacted teeth, reflecting the clinical priorities of the specialty. D'Agostino *et al*. [27] further demonstrated that, beyond broad clinical categories, CBCT imaging is vital for mapping complex anatomical variations and preventing intraoperative complications during surgical interventions. Specifically, the identification of mandibular anomalies, such as bifid and trifid mandibular canals, is clinically important because conventional two-dimensional radiographs may easily mask these secondary canals; therefore, three-dimensional mapping with CBCT is essential to reduce the risk of permanent inferior alveolar nerve injury or neurosensory impairment during complex surgical procedures.

The finding reported by Uvarichev *et al*. [11], that 88.9% of dentists considered CBCT to be the most informative imaging modality, reflects a broad consensus regarding the diagnostic superiority of three-dimensional imaging. In line with this, the superior diagnostic potential of CBCT compared with two-dimensional radiographs also emerged in the present study as the most important reason for its preference (55.2%). Akleyin *et al*. [23] reported a CBCT request rate of 9.64% in pediatric dentistry among patients under 18 years of age, while Ertuğrul and Apaydın [24] reported a CBCT prevalence of 2.1% among pediatric patients aged 5–14 years. Taken together, these findings indicate that CBCT is incorporated into clinical practice through a targeted, indication-specific, and selective approach, rather than being used as a routine screening tool.

There are conflicting findings in the literature regarding the effects of age and professional experience on CBCT-related knowledge. In a study conducted by Yalcinkaya *et al*. [28] among endodontists in Türkiye, dentists aged ≥40 years were reported to have significantly lower CBCT knowledge levels than their younger colleagues. Similarly, Masyte *et al*. [29] reported that the highest level of knowledge regarding CBCT management was observed among dentists with up to 5 years of work experience, whereas those with more than 20 years of experience were rarely familiar with the method. Abdalla-Aslan *et al*. [15] also found a significant relationship between receiving CBCT training and younger age, as well as fewer years of experience. These data support the view, as stated by Cojocaru *et al*. [30], that CBCT technology is more widely adopted among the new generation of dentists.

In contrast, Masyte *et al.* [29] reported that, although knowledge levels were not the highest, the frequency of CBCT use was greatest among dentists with 5–10 years of experience, at 43.9%, whereas those with up to 5 years of experience used the method least frequently. This finding suggests that a certain degree of professional maturity may be required for technological knowledge to translate into clinical practice patterns. However, in the present study, contrary to this general trend in the literature, sex, age, and duration of clinical experience did not significantly affect either knowledge level ($p > 0.05$) or the frequency of CBCT use ($p = 0.126$). Nevertheless, these subgroup findings should be interpreted with caution. Due to the digital distribution of the survey, senior practitioners with 10–15 and >15 years of experience were underrepresented, with only 16 participants in each group, compared with the younger cohort. This demographic imbalance may have reduced the statistical power of the comparative analyses for these specific categories and limited our ability to detect significant differences regarding the long-term impact of clinical experience.

In our study, the most prominent factors limiting CBCT use

among pediatric dentists were “limited indications” (65.6%) and “concern about radiation dose” (59.7%). These findings suggest that pediatric dentists tend to prefer lower-dose imaging methods during the radiologic diagnostic process and remain cautious about CBCT use in accordance with the principle of justification. Similarly, in a survey conducted by Yalda *et al*. [21] in the United Kingdom, only 8.4% of dentists reported using CBCT in pediatric patients, further supporting the view that CBCT is generally reserved for selected indications in pediatric dental practice.

However, the factors limiting CBCT use are not limited to biological risks, as economic and technical barriers also affect clinical decision-making. In the present study, 47.4% and 35.7% of participants identified lack of knowledge and difficulty in interpretation, respectively, as limiting factors. These findings are in line with the results reported by Masyte *et al*. [29], who found that difficulty in software use (22.0%) and time loss during setup procedures (19.5%) were among the practical barriers to CBCT use.

Chinna *et al*. [14] reported that 9% of dentists in their cohort did not prefer CBCT because of its high cost, while Masyte *et al*. [29] also presented cost as one of the main disadvantages. In the present study, 33.8% of participants still considered CBCT a high-cost option compared with conventional methods.

In the study by Yalda *et al*. [21], some dentists used CBCT as a diagnostic alternative in children who could not tolerate intraoral radiographs because of poor cooperation, thereby demonstrating the clinical flexibility of the method in selected cases. Despite the restricted indications identified in the present study, this finding suggests that CBCT may provide a patient-specific diagnostic advantage in certain special situations, provided that its use is justified and optimized within the framework of the ALADAIP principle.

4.1 Strengths of the study

This study contributes to the literature by presenting current data on the clinical use of CBCT in pediatric dentistry and the level of adherence to radiation safety protocols among pediatric dentists in Türkiye, using a statistically adequate and relatively large sample.

4.2 Limitations of the study

As this study was based on an online questionnaire, the data were limited to participants’ self-reports and may have reflected clinical practice in a more idealized manner due to social desirability bias. Although the sample size was statistically adequate, the predominance of participants from academic settings and the incomplete representation of the public and private sectors may limit the generalizability of the findings to Türkiye. Additionally, the distribution of the survey via emails and online communication channels, including WhatsApp and Instagram, may have introduced selection bias, which may partly account for the high proportion of participants with less than 5 years of experience (65.6%), as younger practitioners may be more responsive to digital platforms. Although the predominance of female participants (n = 129, 83.8%) compared with male participants (n = 25, 16.2%) accurately mirrors the demographic reality of pediatric dentistry in Türkiye, this marked gender asymmetry combined with the limited numbers (n = 16) in the 10–15 and >15 years of experience categories inherently reduced the statistical power for these cohorts. Consequently, sub-group analyses regarding both sex-based variations and the effects of long-term clinical experience should be interpreted with caution. Furthermore, although the questionnaire was distributed nationwide through national pediatric dentistry associations to ensure broad coverage, specific demographic data regarding geographic distribution and detailed institution types were not collected. This approach was preferred to keep the survey concise, facilitate completion, and improve participation rates; however, the lack of regional categorization remains a limitation. Direct statistical validation of sample representativeness was also restricted, as a detailed national registry database showing the exact demographic characteristics of all pediatric dentists in Türkiye is currently not publicly available. In addition, due to its cross-sectional design, this study could not monitor long-term changes in a dynamic field such as radiation safety or assess the effects of differences in undergraduate educational curricula.

5. Conclusions

The results demonstrated that although the use of CBCT is becoming more widespread, awareness of radiation safety guidelines remains low, and educational level appears to play an important role in proper protocol selection. In addition, a lack of training among dentists regarding CBCT application and interpretation was identified. These results raise concerns regarding inappropriate CBCT use and the underestimation of risks associated with radiation exposure.

ABBREVIATIONS

AAE & AAOMR, American Association of Endodontists and American Academy of Oral and Maxillofacial Radiology; ALADA, As Low As Diagnostically Acceptable; ALADAIP, As Low As Diagnostically Acceptable for the Individual Patient; ALARA, As Low As Reasonably Achievable; CBCT, cone-beam computed tomography; CT, computed tomography; FOV, field of view; ICRP, International Commission on Radiological Protection; NCRP, National Council on Radiation Protection; SEDENTEXCT, Safety and Efficacy of a New and Emerging Dental X-ray Modality; DIMITRA, Dentomaxillofacial Paediatric Imaging: An Investigation Towards Low-Dose Radiation Induced Risks.

AVAILABILITY OF DATA AND MATERIALS

All data generated or analyzed during this study are included in this published article.

AUTHOR CONTRIBUTIONS

EA and İY—performed the research and coordinated data collection. YPY—provided help and advice on methodology

validation, power analysis, and statistical software implementation. YPY and EA—wrote the manuscript. All authors designed the research study. All authors analyzed the data. All authors contributed to editorial changes in the manuscript. All authors read and approved the final manuscript.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE

This study was conducted in accordance with the Declaration of Helsinki and approved by the Dicle University Non-Interventional Research Ethics Committee, with protocol number 2025-79, dated 30 October 2025. Participants were informed about the purpose of the study, and informed consent was obtained through an online consent form. All participants completed the questionnaire voluntarily.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

SUPPLEMENTARY MATERIAL

Supplementary material associated with this article can be found, in the online version, at https://oss.jocpd.com/files/article/2117515083690983424/attachment/Supplementary%20material.pdf.

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