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Original Article

Investigation of root apical closure of first permanent molars with cone-beam computed tomography: A retrospective study

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KEYWORDS
Cone-beam computed tomography;
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Abstract *Background/purpose:* The objective of this study was to assess the root apical closure ages of first permanent molars retrospectively among a group of western Turkish children aged between 5 and 15 years using cone-beam computed tomography (CBCT).
Materials and methods: CBCT images of 202 patients were examined. The patients were divided into 7 groups according to age: ≤8 years, 8–8.99 years, 9–9.99 years, 10–10.99 years, 11–11.99 years, 12–12.99 years, and ≥13 years. Teeth with at least one open apex were considered as 'teeth with open apex' and teeth with all closed apices were considered as 'teeth with closed apex'. The data was evaluated by Pearson Chi-square test and Fisher's exact test. P value of <0.05 was considered statistically significant.
Results: Apical closure rate of the maxillary first molars was 4.1%, 32.2%, 55.4%, 76.2%, and 90.6% at 8–8.99 years, 9–9.99 years, 10–10.99 years, 11–11.99 years, and 12–12.99 years, respectively. Apical closure rate of the mandibular first molars was 4.4%, 41.2%, 70.7%, 80.0%, and 92.2% at 8–8.99 years, 9–9.99 years, 10–10.99 years, 11–11.99 years, and 12–12.99 years, respectively. At 12–12.99 years, females had a significantly higher rate of closed root apices of mandibular first molars than males ($P < 0.05$). At 9–9.99 and 12–12.99 years,

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females had a significantly higher rate of closed root apices of maxillary molars than males ($P < 0.05$).
Conclusion: CBCT is a useful tool for the evaluation of root development. The results of present study can provide valuable aids for clinicians during root canal treatment of permanent first molars.

Introduction

The tooth root formation begins after the completion of crown morphogenesis and the elaboration of coronal dentin and enamel extracellular matrix.[1] It has been reported that the apical closure of permanent teeth occurs approximately 2—3 years after the teeth emerge into the oral cavity.[2] The development status of root apex has been important for not only the science of endodontics, but also for orthodontics, pediatric dentistry, and forensic dentistry.[3]

Determination of the appropriate time of intervention for orthodontic treatment is a critical issue for the good prognostic outcomes.[4] The identification of specific growth phases with the assessment of skeletal or dental maturity allows clinicians to decide the optimal timing for orthodontic treatment.[5] In pediatric dentistry and endodontics, the knowledge of the apical closure status directly affects the choice of the treatment methods. Especially for the traumatic dental injuries, the healing capacity differs depending on the tooth maturity.[6] Moreover, information on root apex closure of the nonvital teeth allows the clinicians to decide whether to perform root canal treatment or apexification-apexogenesis.[7] In forensic dentistry, different age estimation methods have been used to assess a person's age.[8] Dental age has been used as a reliable indicator of biological age in forensic investigations since the teeth are resistant to decomposition even under unfavorable conditions.[9]

Dental development and consequently root apical closure is a progressive and dynamic process which is influenced by the interactions of genetic, epigenetic, and environmental factors.[10] Within various populations, alterations in tooth development have been reported depending on the gender, race, and systemic conditions. For instance, in a study with Finnish children, girls presented a greater maturity than boys for all age groups.[11] Furthermore, in a meta-analysis which investigated the timing of individual tooth formation stages in children from eight countries, the apical closure of the permanent first molar was significantly later in children from Quebec.[12] In another multi-ethnic, population-based study including Turkish children, it was found that the increase in European ancestral content was associated with a deceleration in dental development approximately 4-to-5 months.[13]

Up to date, dental development was usually investigated based on dental radiographs, mostly by periapical and panoramic radiographs.[14] The introduction of CBCT offered advanced imaging facilities and three-dimensional evaluation of teeth. CBCT could be the most favorable way to study tooth development and dental anatomy since one scan can assess various directions (sagittal, coronal, and transverse) with high quality.[15]

Based on the previous studies, it can be speculated that within different population groups, the pattern of tooth development cannot be considered universal since both hereditary and environmental factors differ. Besides other growth parameters, investigating the root apices closure of first permanent molars with CBCT could guide both dentists and forensic investigations. In this context, to represent the diverse growth patterns in populations, it is important to explore the root apices closure of first permanent molars in individuals across a wide age range.[2] Therefore, the aim of this study was to assess the root apical closure ages of first permanent molars retrospectively among a group of western Turkish children aged between 5 and 15 years using CBCT.

Materials and methods

Study population

The present study was a cross-sectional, descriptive, and retrospective study which was conducted on CBCT images of 202 subjects aged between 5 and 15 years from the database of the Oral and Maxillofacial Radiology clinic of our university.

The inclusion criteria were as follows: children aged between 5 and 15 years at the time that CBCTs were obtained, good-quality radiographs, and no systemic diseases. Patients with extensive dental caries, endodontically treated teeth, extracted permanent molars, gross pathology or agenesis of any permanent teeth were excluded from the study.

Data collection

Demographic data including age, gender, and medical history were recorded from the database. The chronological age of each participant was calculated by subtracting the date of CBCT examination from the date of birth. Months were converted to two decimal years. All data were collected by a single oral and maxillofacial radiologist. To test intra-examiner reproducibility, a random sample of 20 CBCT images were re-examined after an interval of 2 weeks (kappa: 0.98).

All the CBCT images were obtained from patients that were referred to our clinic and required a CBCT scanning as part of their dental examination, diagnosis or treatment. The images were obtained with a NewTom 5G CBCT machine (QR s.r.l., Verona, Italy). The imaging parameters were a tube voltage of 110 kVp, a tube current of 1–20 mA, voxel sizes of 0.2 mm, and a field of view (FOV) of 12 x 8 cm. The images were examined using NNT software (QR s.r.l.) on a medical monitor Radiforce MX270W (Eizo Co., Ishikawa, Japan) in a dark room.

The participants were divided into 7 groups according to age: <8 years, 8–8.99 years, 9–9.99 years, 10–10.99 years, 11–11.99 years, 12–12.99 years, and ≥13 years. All children under the age of 8 had at least one apex open, therefore they were emerged in one single group as '<8'. Each root of maxillary and mandibular first molars was evaluated in axial, sagittal, and coronal planes. The long axis of each root was reformatted to be perpendicular to the axial plane and parallel to the sagittal and coronal planes. In cases where there was a doubt about apical closure, a second radiologist and a pediatric dentist were involved to conduct a definitive evaluation, aiding in the decision-making process. The roots were scored as apex open, and apex closed. Teeth with at least one open apex were considered as 'teeth with open apex' (Fig. 1) and teeth with all closed root apex were considered as 'teeth with closed apex' (Fig. 2).

Statistical analysis

Data entry and all the statistical analysis were performed using IBM SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). Pearson Chi-square test and Fisher's exact test were employed to test associations between root apical closure, age, and gender. A P value of <0.05 was considered statistically significant.

Results

The study samples consisted of 202 CBCT images including 389 maxillary and 385 mandibular molars of children aged between 5 and 15 years, of which; 98 (48.5%) were of female. The number of images was smallest at the age group ≥13 and the largest at the age group 9–9.99 (Table 1).

For the age group of ≤8 years, 100% of both maxillary and mandibular first molars had at least one open root apex. Apical closure rate of the maxillary first molars was 4.1%, 32.2%, 55.4%, 76.2%, and 90.6% at 8–8.99 years, 9–9.99 years, 10–10.99 years, 11–11.99 years, and 12–12.99 years, respectively (Table 2). For the mandibular first molars, the apical closure rate was 4.4%, 41.2%, 70.7%, 80.0%, and 92.2% at 8–8.99 years, 9–9.99 years, 10–10.99 years, 11–11.99 years, and 12–12.99 years, respectively (Table 2). The apical closure status of each root of both maxillary and mandibular molars are summarized in Table 3.

In the older age group (≥13 years), 100% of the root apices of both maxillary and mandibular first molars were closed. At the age group of 12–12.99 years, the apical closure of mandibular first molars showed significant difference by gender that females had a significantly higher rate of closed root apices than males ($P = 0.019$) (Table 4). For both 9–9.99 and 12–12.99 age groups, the apical closure rate of maxillary molars was significantly higher in females than males ($P < 0.05$) (Table 5).

Figure 1 Axial, coronal, and parasagittal cone-beam computed tomography (CBCT) images show a right maxillary first molar with open root apices.

Figure 2 Axial, coronal, and parasagittal cone-beam computed tomography (CBCT) images show a left mandibular first molar with closed root apices.

Table 1 Age and gender distribution of the participants.

Age group (years)	Gender				Total	
	Female		Male			
	N	%	N	%	N	%
<8	10	5.0%	15	7.4%	25	12.4%
8—8.99	13	6.4%	11	5.4%	24	11.9%
9—9.99	22	10.9%	23	11.4%	45	22.3%
10—10.99	18	8.9%	20	9.9%	38	18.8.%
11—11.99	11	5.4%	11	5.4%	22	10.9%
12—12.99	17	8.4%	16	7.9%	33	16.3%
≥13	7	3.5%	8	4.0%	15	7.4%
Total	98	48.5%	104	51.5%	202	100%

Table 2 Proportion of closed apex for permanent first maxillary and mandibular molars by age group.

Age groups (years)	Maxillary molars		Mandibular molars	
	N	%	N	%
<8	0	0%	0	0%
8—8.99	2	4.1%	2	4.4%
9—9.99	28	32.2%	35	41.2%
10—10.99	41	55.4%	53	70.7%
11—11.99	32	76.2%	32	80%
12—12.99	58	90.6%	59	92.2%
≥13	30	100%	30	100%

Discussion

Genetic and environmental interactions cause variations in individuals' growth patterns. This variability could be observed clinically as alterations in the timing and intensity of growing, so that children differ in ages at which they reach stages of physical development. In dentistry, the knowledge of dental maturation is a useful diagnostic tool to determine both the need and time for endodontic and orthodontic treatments.[16] Previous studies have demonstrated that dental development relates more closely to chronological age than other indicators such as skeletal, somatic, or sexual maturity indicators. The variations between different populations relative to the dental maturation markers have been reported in many studies emphasizing the quite big role of ethnicity in that difference.[13,17] Therefore, considering the regional differences, in the current study, our aim was to assess the apical closure age on permanent molars of a group of western Turkish children aged between 5 and 15 years.

Although there are extensive documentations about age estimation using dental age in many populations, studies specifically investigate the apical closure age of permanent molars in children and adolescents is limited. To the best of our knowledge, this is the first study published to date evaluating the root apical closure ages of first permanent molars using CBCT. According to our findings, all the roots of both maxillary and mandibular molars were closed at the age of ≥13 and at the age group of ≤8 years, almost all the roots of both permanent molars were open. At the age group of 10—10.99 years, mesiobuccal and distobuccal roots of maxillary and mandibular teeth had a considerable proportion of closed root apices while only 59.5% of maxillary palatal roots had closed apex. According to the first study on tooth and root development using the histologic and radiographic findings of a limited number of human jaw specimens, root apices closure of first permanent molars occurs at the age between 9 and 10 years.[18] While, in the present study, for only 32.3% of maxillary first molar and 41.2% of mandibular molar, root apices were closed at the same age group. Similarly, in their study using panoramic radiography, Mituro et al.[2] showed that 90% of the root apices of first molars were closed at the age group 10—11.99. In another study using panoramic radiography, Anees et al.[3] reported that the percentage of apical closure observed in maxillary first molars exhibited similarities to our findings within the 5—9 years age group. However, within the 10—15 years age group, our results indicated a comparatively lower percentage of apical closure. The main reason for the variations between the findings of this study and those of previous studies may be attributed to differences in the ethnic backgrounds of the participants or variances in the methodology employed to assess apical closure. According to the literature, CBCT is more accurate than panoramic and periapical radiographies to detect the differences in root structure such as root perforations, external root resorption, and vertical root fractures.[19]

Table 3 Proportion of closed root apices for each root of permanent molars by age group.

Age group (years)	Maxillary molar						Mandibular molar			
	Mesiobuccal root		Distobuccal root		Palatal root		Mesial root		Distal root	
	N	%	N	%	N	%	N	%	N	%
<8	0	0.0%	0	0.0%	0	0.0%	1	2.2.%	0	0.0.%
8—8.99	4	8.2%	7	14.3%	2	4.1%	6	13.3%	2	4.4.%
9—9.99	43	49.4%	48	55.2%	29	33.3%	50	58.8%	36	42.4%
10—10.99	58	78.4%	57	77.0%	44	59.5%	62	82.7%	54	72.0%
11—11.99	36	85.7%	36	85.7%	32	76.2%	35	87.5%	33	82.5%
12—12.99	60	93.8%	60	93.8%	61	95.3%	60	93.8%	59	92.2%
≥13	30	100.0%	30	100.0%	30	100.0.%	30	100.0%	30	100.0%

Table 4 Proportion of open and closed apex for permanent first mandibular molars by age group according to gender.

Age group (years)		Gender		*P*	Total
		Female N (%)	Male N (%)		
<8	Open apex	16 (100.0%)	30 (100.0%)	–	46 (100.0%)
	Closed apex	0 (0%)	0 (0%)		0 (0%)
8–8.99[a]	Open apex	23 (95.8%)	20 (95.2%)	1	43 (95.6%)
	Closed apex	1 (4.2%)	1 (4.8%)		2 (4.4%)
9–9.99[b]	Open apex	21 (51.2%)	29 (65.9%)	0.169	50 (58.8%)
	Closed apex	20 (48.8%)	15 (34.1%)		35 (41.2%)
10–10.9[b]	Open apex	10 (28.6%)	12 (30.0%)	0.892	22 (29.3%)
	Closed apex	25 (71.4%)	28 (70.0%)		53 (70.7%)
11–11.99[a]	Open apex	2 (10.0%)	6 (30.0%)	0.235	8 (20.0%)
	Closed apex	18 (90.0%)	14 (70.0%)		32 (80.0%)
12–12.99[a]	Open apex	0 (0.0%)	5 (16.7%)	**0.019***	5 (7.8%)
	Closed apex	34 (100.0%)	25 (83.3%)		59 (92.2%)
≥13	Open apex	0 (0%)	0 (0%)	–	0 (0%)
	Closed apex	14 (100.0%)	16 (100.0%)		30 (100.0%)

Teeth with at least one open apex were considered as 'teeth with open apex' and teeth with all closed root apex were considered as 'teeth with closed apex'.
The significance level was set to $P < 0.05$. *: $P < 0.05$.
[a] Fisher's exact test.
[b] Chi-square test.

Table 5 Proportion of open and closed apex for permanent first maxillary molars by age group according to gender.

Age group (years)		Gender		*P*	Total
		Female N (%)	Female N (%)		
<8	Open apex	14[a] (100.0%)	29[a] (100.0%)	–	43 (100.0%)
	Closed apex	0 (0)	0 (0)		0 (0)
8–8.99[a]	Open apex	26[a] (92.9%)	21[a] (100.0%)	0.500	47 (95.9%)
	Closed apex	2[a] (7.1%)	0[a] (0.0%)		2 (4.1%)
9–9.99[b]	Open apex	22[a] (53.7%)	37[b] (80.4%)	**0.008****	59 (67.8%)
	Closed apex	19[a] (46.3%)	9[b] (19.6%)		28 (32.2%)
10–10.99[b]	Open apex	17[a] (50.0%)	16[a] (40.0%)	0.388	33 (44.6%)
	Closed apex	17[a] (50.0%)	24[a] (60.0%)		41 (55.4%)
11–11.99[a]	Open apex	3[a] (13.6%)	7[a] (35.0%)	0.152	10 (23.8%)
	Closed apex	19[a] (86.4%)	13[a] (65.0%)		32 (76.2%)
12–12.99[a]	Open apex	0[a] (0.0%)	6[b] (20.0%)	**0.008****	6 (9.4%)
	Closed apex	34[a] (100.0%)	24[b] (80.0%)		58 (90.6%)
≥13	Open apex	0[a] (0.0%)	0[a] (0.0%)	–	0_a (0.0%)
	Closed apex	14[a] (100.0%)	16[a] (100.0%)		30 (100.0%)

Teeth with at least one open apex were considered as 'teeth with open apex' and teeth with all closed root apex were considered as 'teeth with closed apex'.
The significance level was set to $P < 0.05$. **: $P < 0.01$.
[a] Fisher's exact test.
[b] Chi-square test.

Therefore, present study seems more reliable than the previous studies due to the employed method.

Besides gender and ethnicity, root development may be influenced by overall health, vitamin D deficiency, and dietary factors.[20,21] In this study, participants with systemic diseases were excluded to mitigate the impact of general health considerations on root development. Nevertheless, the retrospective design of the study precluded the analysis of participants' diets, constituting a limitation. Further studies should address confounding factors, including diet and vitamin D deficiency, to provide a more comprehensive understanding of the subject. Moreover, the outcomes of studies assessing apical closure may be subject to methodological influences. To address this concern, research comparing the accuracy of CBCT with alternative measurement methods in the evaluation of root apical closure may be beneficial.

In the literature, differences in dental development have been found between not only in different ethnic groups, but also genders. There are studies found that females show faster,[22] equal[23] or delayed[24] dental maturation than males. Moreover, in a similar study investigating the apical closure age of first permanent molars in Tanzanian children, no gender differences have been found in root apices closure of permanent molars.[2] According to our findings, at the age group of 12—12.99 years, females showed significantly higher proportion of apical closure for both maxillary and mandibular first molars than males. Furthermore, at the age group of 9—9.99 years, females also showed significantly higher proportion of apical closure for maxillary first molars. As females have precocious puberty compared to males, these differences could be attributed to the pre-pubertal or pubertal growth changes pertinent during this age period.

The present study was a hospital-based study which included subjects who were undergoing dental treatment or orthodontic follow-up; therefore, the results of this study may not be representative of the general population. For epidemiological purposes, the study group should have been larger. However, CBCT imaging of children and adolescents is not as common as panoramic radiograph. Therefore, the sample size in this study provides a satisfactory starting point for future research.

In the present study, CBCT-constructed 3D images were used retrospectively to investigate the apical zone of relevant teeth. As Ginzelova et al. concluded that, CBCT images display more aptly the apical area in greater detail than the panoramic images.[9] Despite its numerous benefits, the primary concern associated with CBCT is the radiation dose. The radiation exposure from CBCT is significantly lower compared to multi-slice computed tomography. Nevertheless, it exceeds that of intraoral and extraoral radiographs commonly used in dentistry.[25] In addition, children are 2—10 times more sensitive to ionizing radiation than adults due to faster cell division.[26] Therefore, it is crucial to reserve the use of CBCT in pediatric patients solely for necessary indications. If a CBCT examination is deemed necessary, employing dose-reduction strategies becomes imperative. These strategies include limiting the scanned area, utilizing organ protectors, selecting appropriate acquisition parameters based on the child's age and body weight, and minimizing the repetition of imaging.[27,28]

Based on the results of our study, CBCT is a useful tool for the evaluation of root development. Our results can provide valuable aids for clinicians during root canal treatment of permanent first molars.

Declaration of competing interest

The authors have no conflicts of interest relevant to this article.

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References

1. Thomas HF. Root formation. *Int J Dev Biol* 1995;39:231—7.
2. Mituro TH, Mugonzibwa EA, Kahabuka FK. A retrospective study of root apices closure of permanent incisors and first molars in Tanzanian children's digital orthopantomographs. *Oral Biol Dent* 2018;6:1—6.
3. Anees W, Shah FM, Khan JN, et al. Assesment of root apices closure of permanent incisors and first molars in digital orthopantomographs: a pilot study from Pakistan. *Pakistan J Med Sci* 2022;16:797—9.
4. Fleming PS, Andrews J. Orthodontic treatment: getting the timing right. *Semin Orthod* 2023;29:137—45.
5. Jourieh A, Khan H, Mheissen S, Assali M, Alam MK. The correlation between dental stages and skeletal maturity stages. *BioMed Res Int* 2021;2021:1—7.
6. Levin L, Day PF, Hicks L, et al. International association of dental traumatology guidelines for the management of traumatic dental injuries: general introduction. *Dent Traumatol* 2020;36:309—13.
7. Saxena N, Hugar SM, Soneta SP, Joshi RS, Dialani PK, Gokhale N. Evaluation of the treatment protocols in the management of pulpally involved young permanent teeth in children: a systematic review and meta-analysis. *Int J Clin Pediatr Dent* 2022;15:103—13.
8. Sezer B, Çarıkçıoğlu B. Accuracy of the London Atlas, Haavikko's Method and Cameriere's European Formula of dental age estimation in Turkish children. *Leg Med* 2022;54:101991.
9. Ginzelova K, Dostalova T, Eliasova H, Bruna R, Vinsu A. Comparison of dental and chronological age based on CBCT-generated panoramic images and reconstructed 3D images. *Anthropol Anzeiger* 2019;76:49—56.
10. Khalaf K, Brook AH, Smith RN. Genetic, epigenetic and environmental factors influence the phenotype of tooth number, size and shape: anterior maxillary supernumeraries and the morphology of mandibular incisors. *Genes* 2022;13:2232.
11. Chaillet N, Nyström M, Kataja M, Demirjian A. Dental maturity curves in Finnish children: demirjian's method revisited and polynomial functions for age estimation. *J Forensic Sci* 2004;49:1324—31.
12. Liversidge H, Chaillet N, Mörnstad H, et al. Timing of Demirjian's tooth formation stages. *Ann Hum Biol* 2006;33:454—70.
13. Dhamo B, Kragt L, Grgic O, et al. Ancestry and dental development: a geographic and genetic perspective. *Am J Phys Anthropol* 2018;165:299—308.
14. Asif MK, Ibrahim N, Khan IM, Khan SS, Nambiar P. Dental age estimation of Malaysian children: a comparison of two-dimensional versus three-dimensional imaging analyses of the developing root apices. *Ann Hum Biol* 2022;49:109—15.
15. Mashyakhy M, Awawdeh M, Abu-Melha A, et al. Anatomical evaluation of root and root canal configuration of permanent maxillary dentition in the population of the Kingdom of Saudi Arabia. *BioMed Res Int* 2022;2022:1—12.
16. Kurita LM, Menezes AV, Casanova MS, Haiter-Neto F. Dental maturity as an indicator of chronological age: radiographic assessment of dental age in a Brazilian population. *J Appl Oral Sci* 2007;15:99—104.
17. Kurniawan A, An Chusida, Atika N, et al. The applicable dental age estimation methods for children and adolescents in Indonesia. *Int J Dent* 2022;2022:1—6.
18. Logan WH, Kronfeld R. Development of the human jaws and surrounding structures from birth to the age of fifteen years. *J Am Dent Assoc* 1933;20:379—428.
19. Takeshita WM, Chicarelli M, Iwaki LCV. Comparison of diagnostic accuracy of root perforation, external resorption and fractures using cone-beam computed tomography, panoramic radiography and conventional & digital periapical radiography. *Indian J Dent Res* 2015;26:619—26.
20. Atar M, Körperich EJ. Systemic disorders and their influence on the development of dental hard tissues: a literature review. *J Dent* 2010;38:296—306.

21. Li Z, Wei X, Shao Z, Liu H, Bai S. Correlation between vitamin D levels in serum and the risk of dental caries in children: a systematic review and meta-analysis. *BMC Oral Health* 2023; 23:768.
22. Tunc ES, Koyuturk AE. Dental age assessment using Demirjian's method on northern Turkish children. *Forensic Sci Int* 2008; 175:23—6.
23. Altunsoy M, Nur BG, Akkemik O, Ok E, Evcil MS. Applicability of the Demirjian method for dental age estimation in western Turkish children. *Acta Odontol Scand* 2015;73: 121—5.
24. Miloglu O, Celikoglu M, Dane A, Cantekin K, Yilmaz AB. Is the assessment of dental age by the Nolla method valid for eastern Turkish children? *J Forensic Sci* 2011;56:1025—8.
25. Abuzaid MM, Elshami W, Jayachandran D, Korappil N, Tekin HO. Establishment of diagnostic reference levels in cone beam computed tomography scans in the United Arab Emirates. *Tomography* 2022;8:2939—45.
26. Gricienė B, Šiukšterytė M. Local diagnostic reference levels for paediatric head CT procedures. *Acta Med Litu* 2021;28: 253—61.
27. Akleyin E, Eskibağlar BK. Reasons for requesting cone-beam computed tomography in children and adolescents: a 10-year study. *Biotechnol Biotechnol Equip* 2022;36:858—64.
28. Yiğit T, Yüksel HT, Ş Evirgen, Kaçmaz I, Türkmenoğlu A. Evaluation of use of cone beam computed tomography in paediatric patients: a cross-sectional study. *Int J Paediatr Dent* 2023;33:468—76.