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Original research

Radiodiagnostic analysis of dens invaginatus in maxillary lateral incisors: a cone-beam computed tomographic study

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Purpose

This study aims to determine the prevalence of dens invaginatus (DI) in maxillary lateral teeth within a Turkish subpopulation using cone-beam computed tomography (CBCT) and to evaluate the relationship between the invagination and the main root canal.

Materials and Methods

A total of 953 maxillary lateral teeth from 662 patients were evaluated for the presence of DI. To ascertain the invagination's location in the crown from the axial section, four equidistant areas were delineated, extending from the mesio-palatal to the disto-palatal surface. Measurements included the vertical distance between the top of the palatal pulp horn and the buccal pulp horn (h1), the closest distance between the invagination and the buccal pulp horn (h2), and the dentin thickness from the widest part of the invagination to the tooth's outer walls.

Results

DI was observed in 5% of the patients (33/662). Invaginations in the medial region of the mesiopalatinal surface were statistically significantly more common in males (p=0.049). The distances from the invagination to the buccal and distal walls were also significantly longer in males (p=0.040 and p=0.008, respectively). There was no statistically significant difference in the mean distances h1 and h2 according to sex and age.

Conclusion

Based on CBCT measurements, investigating the presence of DI more mesiopalatinally in males is recommended to prevent excessive tooth structure loss. Additionally, given that DI is significantly closer to the buccal and distal walls in females, a more conservative access cavity approach should be advised to minimize the risk of perforation.

Keywords: *Cone-beam computed tomography, dens invaginatus, prevalence, root canal treatment, tooth abnormalities*

Introduction

Dens invaginatus (DI) is a developmental dental anomaly that occurs during tooth development when the enamel organ folds into the dental papilla before calcification is complete (1). Although the etiology of DI remains unclear, factors such as infection, trauma (2,3), localized growth failure of the internal enamel epithelium, external pressures exerted by adjacent tooth germs during tooth development, and genetic influences are considered to play a role (4).

DI has been categorized into different types by numerous researchers, but the classification proposed by Oehlers (5) is the most widely used. This classification is based on clinical and radiographic features, focusing on the depth of penetration and its relationship with the periapical tissue and the periodontal ligament. It includes Type 1, where the invagination

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is confined to the crown and affects the enamel and dentin; Type 2, which extends beyond the cementoenamel junction and may involve the pulp; and Type 3, where the invagination extends beyond the cementoenamel junction and penetrates through the root, creating an additional apical or lateral foramen.

The incidence of DI has been reported to range from 0.25% to 26.5% among examined patients, with the percentage of affected teeth varying from 0.3% to 10% according to the literature (4). Maxillary lateral incisors are the most commonly affected teeth (6-8).

DI is usually diagnosed incidentally during clinical and radiographic examinations, often without any symptoms. The morphology of invaginated teeth may appear normal or exhibit abnormal crown morphology (8). Radiographically, DI presents as a radiopacity equivalent to enamel, resembling a small tooth within the coronal pulp cavity, beginning below the cingulum, extending through the root canal, and sometimes reaching the apex (9).

Abnormal changes in the morphology of the invaginated tooth can allow microorganisms to access the invagination area, directly or indirectly affecting the pulp. This can lead to conditions that initially start with pulpitis and may result in signs or symptoms associated with apical or marginal periodontitis (10). Additionally, DI can cause abscess formation, internal resorption, tooth displacement, and impaction of adjacent teeth (1).

Treatment options for DI range from conservative treatments to root canal treatment, endodontic apical surgery, intentional replantation, and extraction (1). Particularly when planning conservative treatment and root canal treatment, precautions should be taken to avoid perforations during the cleaning of the infected area and the opening of the access cavity (11). Understanding the anatomical relationship between the invagination and the main canal with an effective imaging tool is crucial for the treatment approach. However, traditional two-dimensional radiographs may not adequately reveal the malformation due to the complex anatomy of invaginated teeth (10). Cone-beam computed tomography (CBCT) is more effective than two-dimensional imaging methods in various dentistry fields (12), although it delivers a higher radiation dose and should not be used routinely in every patient (13). It is preferred in cases where traditional radiographs are insufficient, particularly in DI cases where endodontic management is complicated by factors such as endodontic lesions and complex pulpal anatomy (13). Most studies on the incidence of DI have been conducted using two-dimensional radiographs (14-16); only a few have utilized CBCT (6,17,18). Moreover, no study has analyzed the relationship between invagination and the main root canal using CBCT in the literature.

This study aims to determine the incidence of DI in maxillary lateral teeth in the Turkish subpopulation using CBCT and to evaluate the relationship between invagination and the main canal through various anatomical measurements. The null hypothesis was formulated as follows: there is no significant difference in the prevalence of DI in maxillary lateral teeth between males and females in a Turkish subpopulation, and there is no significant relationship between the presence of DI and the anatomical variations in the root canal system as observed through CBCT.

Materials and Methods

Ethical approval

The study was approved by the Clinical Research Ethics Committee (Number:2022/185). Informed consent forms were obtained from the patients.

Study design

In this study, 662 patients who presented to the Department of Oral and Maxillofacial Radiology between 2017 and 2020 for various reasons and whose CBCT images were taken, and at least one of the upper lateral teeth entered the imaging field were evaluated.

CBCT data acquisition and measurements

All CBCT images of the patients were taken using a Planmeca ProMax 3D Classic (Planmeca Promax 3D; Planmeca Oy; Helsinki, Finland) device with the following parameters: 90 kVp, 4–10 mA, and voxel size 75-200 µm. Images were evaluated using the Planmeca Romexis 4.6.2.R software (PLANMECA Romexis, Helsinki, Finland). Images with insufficient diagnostic quality and those in which any maxillary lateral tooth did not fully enter the imaging area were excluded. In addition, teeth with root canal treatment, apical lesions, prosthetic restoration, and restorative treatment were also excluded.

Nine hundred fifty-three maxillary lateral teeth of 662 patients who met the criteria were included in the study. Demographic characteristics and invagination types were recorded. While type 3 DI was observed in only 2 teeth, type 1 DI was detected in 40 teeth. Since statistically significant results could not be obtained for type 3 DI, radiomorphometric measurements and statistical evaluations were performed only for type 1 DI.

Patients who had type 1 DI were divided into five groups according to age: group 1: 17-26 years, group 2: 27-35 years, group 3: 36-44 years, group 4: 45-53 years, and group 5: 54-62 years. In this retrospective study, no invagination located buccal side in the axial section was encountered therefore, the location of invagination was classified in the palatal region. After the long axis of the tooth was set perpendicular to the ground plane, to determine the location of the invagination in the crown from the axial section, four different areas divided by 45-degree equal angles on the 180-degree plane extending from the mesio-palatal surface to the disto-palatal surface were determined and numbered from 1 to 4.

Region 1: the 45-degree part laterally on the mesiopalatinal site;

Region 2: the 45-degree part remaining medially on the mesiopalatinal site;

Region 3: the 45-degree part remaining medially on the distopalatinal site;

Region 4: the 45-degree part laterally on the distopalatinal site.

Furthermore, as the invagination area has oval or round shape, invaginations may not always be located only in the 2nd, 3rd, or 4th regions in some of the cases. Therefore, invaginations with extensions in both the 2nd and 3rd regions are referred to as regions 2-3, while invaginations with extensions in both the 3rd and 4th regions are named regions 3-4. (Figure

1). After the long axis of the tooth was adjusted perpendicular to the ground plane on the sagittal slice, the vertical distance between the top of the palatal pulp horn and the top of the buccal pulp horn was measured as h1 (Figure 2A). In the axial slice, the dentin thickness from the widest part of the invagination area to the outer walls of the tooth was measured; these distances were recorded as buccal, palatal, distal, and mesial dentin thicknesses (Figure 2B). In the axial slice, the distance where the invagination area and the buccal pulp horn were closest to each other was measured as h2 (Figure 3). All images were evaluated by a radiologist (T.E.K) with 10+ years of clinical experience. Twenty randomly selected images for intra-examiner correlation were re-evaluated two weeks later.

Statistical analysis

SPSS v.25 (Statistical Package for Social Sciences, IBM SPSS, Armonk, NY, USA) software was used for statistical analysis. The relationship between the presence of DI with sex was performed using the Pearson Chi-square test. The Fisher's Exact test was used to examine the relationship between the location of DI and sex. Statistical evaluation of h1, h2, buccal, palatal, distal, and mesial dentin thicknesses related to sex was analysed by Independent Sample T-test, and statistical evaluation by age was analysed using Kruskal-Wallis test. The confidence interval was set to 95% and a level of $p<0.05$ was established for statistical significance.

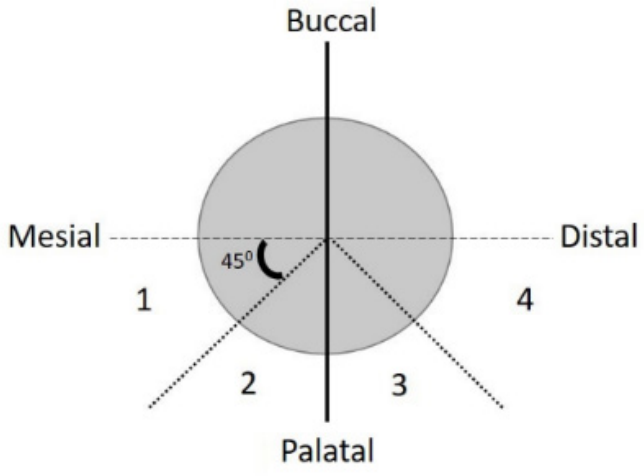

Figure 1. *Locations of dens invaginatus.*

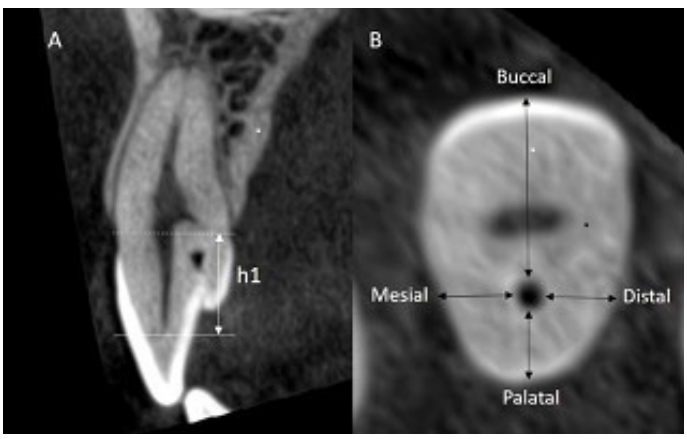

Figure 2. *The vertical distance between the apex of the palatal pulp horn and the buccal pulp horn (A,h1), and the distances from the widest point of the invagination to the buccal, palatal, distal, and mesial (B) are shown*

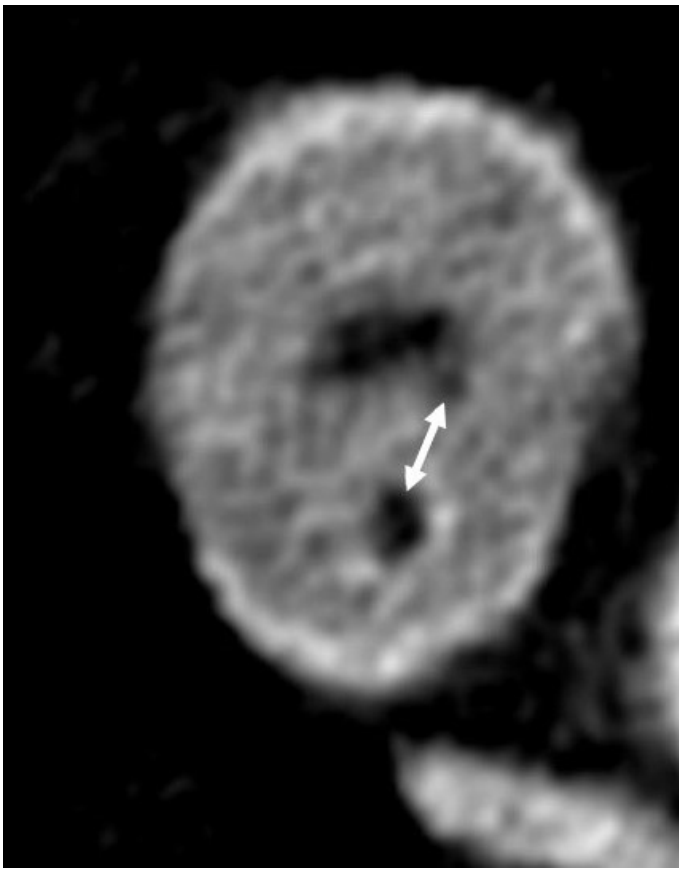

Figure 3. *The closest distance between the invagination area and the buccal pulp horn in the axial slice (h2) is shown.*

Results

The age of the 662 patients ranged from 11 to 82 (mean: 38.24, standard deviation 14.50) years. There were 361 (54.5%) females and 301 (45.5%) males. DI was detected in 33 of 662 patients, with a prevalence of 5%. Although invagination was more common in males (6.6%) than females (3.6%), there was no statistically significant difference between the sexes (p=0.073) (Table 1). DI was detected in 42 maxillary lateral teeth. The majority (95.2%) of invaginations were classified as type 1, and 4.8% were type 3; no type 2 invagination was found in CBCT.

When the regions of invagination were examined according to sex, invagination was not found in regions 1and 4. Invagination was located in regions 2-3 the most, with a 60% incidence rate. Invagination occurred in 12.5% of females and 41.7% of males in region 2; 6.25% of females and 8.3% of males had invagination in region 3; 75% of females and 50% of males had invagination located in regions 2-3. In addition, 6.25% of the females had invagination in regions 3-4; invagination was not seen in this region in any males. According to the Chi-square test, there was no statistically significant difference between the location regions of DI and sex (p=0.112). In contrast, invaginations in region 2 were statistically significantly more frequent in males than in females (p=0.049) (Table 2). Examinations of h1 and h2 values are

shown in Table 3. According to these data, when mean values of h1 were compared with sex and age, the significance was not statistically different (p=0.968) (p=0.158). Also, the relationship between sex and age and h2 values was not statistically significant (p=0.354) (p=0.243). The data obtained for the distances of invagination to the buccal, mesial, distal, and palatal walls of the tooth in the axial slice are shown in Table 3. There was no statistically significant difference between the mean distances of the invagination to the palatal and mesial walls according to sex (p=0.083, p=0.085, respectively) but the mean distance to the buccal and distal walls was significantly longer in men than in women (p=0.040, p=0.008 respectively). In addition, there was no significant difference between the age groups in the distances of the invagination to the outer walls (Table 3).

Discussion

CBCT imaging can be a more effective tool than two-dimensional imaging methods for diagnosing Dentin Invagination (DI) and planning appropriate treatment. Various studies using periapical and/or panoramic radiography reported the incidence of DI as 1.3% (14), 2.5% (15), and 2.95% (7), whereas studies employing CBCT found incidences of 5.9% (17), 7.3% (20), 10.7% (6), and 12.5% (21). Consistent with CBCT studies, our study found a DI incidence of 5%. These variations can be attributed to the higher diagnostic likelihood of DI with CBCT, differences in sample size, and varied inclusion criteria (19).

Table 1. *Prevalence of Dens Invaginatus (DI).*

Patients	Sex		Total (%)	p
	Female (%)	Male (%)		
Patients without DI	348 (96.4)	281 (93.4)	629 (95.0)	0.073
Patients with DI	13 (3.6)	20 (6.6)	33 (5.0)	
Total	361 (54.5)	301 (45.5)	662 (100.0)	

Maxillary lateral incisors are most commonly affected by DI (1,22). The incidence of DI in these teeth, compared to others, was reported as 98.6% (22), 75% (6), 62% (16), and 53.7% (18) in various studies, prompting our CBCT study to focus on maxillary lateral teeth. Gündüz *et al.* (15) reported a higher prevalence of DI in males, while Chen *et al.* (22) found it more common in females. Other studies (8,14,17,18) found no significant sex differences. In our research, although DI was observed more in males than in females, the difference was not statistically significant.

According to Oehlers' classification, type 1 DI is the most common invagination with an incidence of 69.8-93.8%, type 2 DI is 3.1-26.6%, and type 3 DI frequency is 3-12.5% (14,16). In our study, type 1 DI was the most common (95.2%), followed by type 3 DI (4.8%). Type 2 DI was not found. The disparity in the results of these studies may be attributable to sample size, case selection, significant differences in the methods used, diagnostic criteria, and geographic factors (7).

In almost all teeth with DI, an approach to invagination is recommended regardless of the condition of the pulp, to prevent pulpal involvement and pulpal necrosis. However, preparation of the access cavity is often technically difficult due to the location of the pulp chamber and invagination area (11). Therefore, understanding the anatomic relationship between invagination and the main canal with a good imaging tool such as CBCT is of great importance in the treatment approach.

The invagination is separated from the pulp by only a thin layer of enamel and dentin. Therefore, the risk of sources of irritation and microorganisms infecting the pulp is higher in invaginated teeth. If the invagination area interacts with the pulp and shows signs of pulpal infection, root canal treatment is necessary, whereas if the pulp is not infected, conservative treatment of the invaginated area is very effective in maintaining the vitality of the pulp (4,23). At these stages, minimal instrumentation is recommended to prevent further weakening of the tooth. To this end, using low-speed burs or ultrasonic instruments creates a more controlled treatment protocol (24,25). In addition, recently, there have been successful studies aiming to create a more conservative access cavity using guide splints in invaginated

Table 2. *Locations of Type 1 Dens Invaginatus.*

	Sex		Total (%)	p
Location of DI (region)	**Female (%)**	**Male (%)**		
2	2 (12.5)	10 (41.7)	12 (30.0)	0.112
3	1 (6.25)	2 (8.3)	3 (7.5)	
2-3	12 (75.0)	12 (50.0)	24 (60.0)	
3-4	1 (6.25)	0 (0.0)	1 (2.5)	
Total	16 (40.0)	24 (60.0)	40 (100.0)	
Location of region 2	**Female (%)**	**Male (%)**	**Total (%)**	**p**
No	14 (87.5)	14 (58.3)	28 (70.0)	**0.049***
Yes	2 (12.5)	10 (41.7)	12 (30.0)	
	16 (40.0)	24 (60.0)	40 (100.0)	

DI: dens invaginatus Region 2: 45-degree part remaining medially on the mesiopalatinal site; Region 3: the 45-degree part remaining medially on the distopalatinal site; Region 2-3: invaginations with extensions in both the 2nd and 3rd regions; Region 3-4: invaginations with extensions in both the 3rd and 4th regions *$p<0.05$

Table 3. *Comparison of h1, h2, Buccal, Mesial, Distal, and Palatinal Measurements by Sex and Age.*

Dental Analysis			n	Minimum	Maximum	Mean	Standard deviation	p
h1	**Sex**	Female	16	3.23	7.40	5.35	1.23	0.968
		Male	24	3.40	8.00	5.33	1.31	
	Age	17-26	20	3.23	8.00	5.61	1.47	
		27-35	7	4.05	6.20	5.21	0.76	
		36-44	5	4.20	6.60	5.04	0.98	0.158
		45-53	4	3.40	4.60	4.00	0.52	
		54-62	4	5.00	7.20	5.90	0.93	
h2	**Sex**	Female	16	0.24	1.66	0.89	0.37	0.354
		Male	24	0.20	1.76	1.01	0.32	
	Age	17-26	19	0.20	1.66	0.85	0.34	
		27-35	7	0.63	1.42	1.03	0.34	
		36-44	6	0.40	1.76	1.12	0.48	0.243
		45-53	4	1.00	1.13	1.04	0.06	
		54-62	4	1.00	1.26	1.07	0.13	
Buccal	**Sex**	Female	15	2.77	4.58	3.99	0.47	**0.040***
		Male	25	3.40	5.60	4.36	0.57	
	Age	17-26	20	3.23	8.00	5.61	1.47	
		27-35	7	4.05	6.20	5.21	0.76	
		36-44	5	4.20	6.60	5.04	0.98	0.158
		45-53	4	3.40	4.60	4.00	0.52	
		54-62	4	5.00	7.20	5.90	0.93	
Mesial	**Sex**	Female	16	1.20	2.00	1.68	0.25	0.085
		Male	25	1.20	2.80	1.85	0.33	
	Age	17-26	20	3.23	8.00	5.61	1.47	
		27-35	7	4.05	6.20	5.21	0.76	
		36-44	5	4.20	6.60	5.04	0.98	0.158
		45-53	4	3.40	4.60	4.00	0.52	
		54-62	4	5.00	7.20	5.90	0.93	
Distal	**Sex**	Female	16	0.82	2.80	1.72	0.47	**0.008***
		Male	25	1.20	2.85	2.10	0.40	
	Age	17-26	20	3.23	8.00	5.61	1.47	
		27-35	7	4.05	6.20	5.21	0.76	
		36-44	5	4.20	6.60	5.04	0.98	0.158
		45-53	4	3.40	4.60	4.00	0.52	
		54-62	4	5.00	7.20	5.90	0.93	
Palatinal	**Sex**	Female	16	0.20	1.95	1.35	0.43	0.083
		Male	24	0.80	2.40	1.58	0.37	
	Age	17-26	20	3.23	8.00	5.61	1.47	
		27-35	7	4.05	6.20	5.21	0.76	
		36-44	5	4.20	6.60	5.04	0.98	0.158
		45-53	4	3.40	4.60	4.00	0.52	
		54-62	4	5.00	7.20	5.90	0.93	

h1: The vertical distance between the apex of the palatal pulp horn and the buccal pulp horn, measured in mm, *h2*: The closest distance between the invagination area and the buccal pulp horn from the axial slice, measured in mm, **p<0.05*

teeth (26,27). However, preparing a guide splint is a costly procedure and requires a longer treatment time. Complications such as the separation of the roller guide from the splint and fracture of the splint have also been reported (28). Therefore, it may not always be possible to use a guide splint in the treatment of DI. According to the analyses performed in our study, the data obtained regarding the position and distance of the invagination relative to the main canal were very important for the determination of the invagination area during the preparation of the access cavity. Especially when the treatment of only the invagination area is planned for teeth that have no problems in the main canal, the data on which region the invagination is located can guide clinicians in where to look during the creation of the access cavity. In our study, invagination was located just palatal to the main canal (regions 2-3) in most patients (60%). In females (75%), it was located predominantly just palatal to the main canal (regions 2-3), whereas, in males, it was located palatal

(50%) of the main canal (regions 2-3) or very slightly mesiopalatally (41.7%) (region 2). Positioning of invagination in region 2 was significantly more frequent in males than in females. Therefore, these data may suggest that we should look for invagination more mesiopalatally in men, and thus prevent loss of excessive tooth structure.

If the pulp horns are not included in the access cavity in the root canal treatment, infected or necrotic pulp residues remaining in these areas adversely affect the success of the treatment. According to the data in our study, the h1 distance is similar on average in males and females (5.35 and 5.33 mm, respectively). These values are very important for the inclusion of the pulp horns in the cavity and the complete cleaning of pulpal residues in this area.

In our study, the mean h2 distance was determined as 1.01 mm in males and 0.89 mm in females. Accordingly, if vital treatment is planned in cases where the invagination area is affected but the pulp in the main canal is healthy, not making excessive expansion in the invagination area may be beneficial in terms of protecting the main canal and thus maintaining pulpal health.

Average values for the distance of invagination to the outer walls of the tooth are very important in preventing iatrogenic perforations during cavity preparation. According to our study findings, invagination was closest to the palatal wall (mean 1.46 mm), followed by the mesial (mean 1.76 mm) and distal (mean 1.91 mm) walls, respectively. For this reason, the risk of perforation in these regions should be taken into account during the cavity access stage and should be treated in a controlled manner, especially in the palatal region. In addition, the distance to the buccal and distal walls in females was significantly shorter than in males. For this reason, it is thought that more conservative access cavity planning in females than in males will be effective in reducing the risk of perforation.

Conclusion

DI was located more mesiopalatally in males, whereas, it was significantly closer to the buccal and distal walls in females. Therefore, to reduce the risk of perforation in these critical anatomical structures, a more conservative approach to the access cavity could be suggested.

Türkçe öz: *Üst çene yan kesici dişlerde görülen dens invajinatusun radyodiagnostik analizi: bir konik ışınlı bilgisayarlı tomografi çalışması. Amaç: Türk alt popülasyonunda maksiller lateral dişlerde görülen dens invajinatusun (Dİ) prevalansını konik ışınlı bilgisayarlı tomografi (KIBT) kullanarak belirlemek ve invajinasyon ile ana kök kanalı arasındaki ilişkiyi değerlendirmek. Gereç ve Yöntem: 662 hastada toplamda 953 maksiller lateral diş Dİ varlığı açısından değerlendirildi. Aksiyal kesitten invajinasyonun koronaldeki yerleşim yerini belirlemek için mesiopalatinal yüzeyden distopalatinal yüzeye uzanan 4 eşit farklı bölge belirlendi. Palatinal pulpa boynuzunun tepe noktası ile bukkal pulpa boynuzunun tepe noktası arasındaki vertikal mesafe (h1), invajinasyon ile bukkal pulpa boynuzu arasındaki en yakın mesafe (h2) ve invajinasyonun en geniş yerinden dişin dış duvarlarına uzanan dentin kalınlığı ölçüldü. Bulgular: Hastaların %5'inde (33/662) Dİ gözlendi. Mesiopalatinal yüzeyin medial tarafında görülen invajinasyonlar erkeklerde istatistiksel olarak önemli ölçüde daha fazlaydı (p=0,049). İnvajinasyonun bukkal ve distal duvarlara olan uzaklıkları da erkeklerde önemli ölçüde daha fazlaydı (sırasıyla p=0,040 ve p=0,008). Cinsiyet ve yaşa göre ortalama h1 ve h2 değerleri arasında istatistiksel olarak anlamlı bir fark bulunmadı. Sonuç: KIBT ölçümleri göz önüne alındığında, diş yapısının aşırı kaybını önlemek için Dİ' nin erkeklerde daha mesiopalatinal bölgede araştırılması önerilebilir. Ayrıca, Dİ kadınlarda dişin bukkal ve distal duvarlarına önemli ölçüde daha yakın olduğundan, perforasyon riskini azaltmak için daha konservatif bir giriş kavitesi önerilebilir. Anahtar Kelimeler: Konik ışınlı bilgisayarlı tomografi; dens invajinatus; prevalans; kök kanal tedavisi; diş anomalileri*

Ethics Committee Approval: The study was approved by the Clinical Research Ethics Committee (Number:2022/185). Informed consent forms were obtained from the patients.

Informed Consent: Participants provided informed constent.

Peer-review: Externally peer-reviewed.

Author contributions: NCU, ASC, TEK, DNG participated in designing the study. NCU, ASC, TEK, DNG participated in generating the data for the study. NCU, ASC, TEK, DNG participated in gathering the data for the study. NCU, ASC, TEK, DNG participated in the analysis of the data. NCU, ASC, TEK, DNG wrote the majority of the original draft of the paper. NCU, ASC, TEK, DNG participated in writing the paper. NCU, ASC, TEK, DNG has had access to all of the raw data of the study. NCU, ASC, TEK, DNG has reviewed the pertinent raw data on which the results and conclusions of this study are based. NCU, ASC, TEK, DNG have approved the final version of this paper. NCU, ASC, TEK, DNG guarantees that all individuals who meet the Journal's authorship criteria are included as authors of this paper.

Conflict of Interest: The authors declared that they have no conflict of interest.

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