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Pre-eruptive intracoronal resorption in orthodontic patients: A retrospective analysis of 3,143 patients

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A R T I C L E I N F O

Keywords:
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PIR
PEIR
Radiolucent lesion

A B S T R A C T

Objectives: The aim of this retrospective study was to analyze the occurrence and characteristics of pre-eruptive intracoronal resorptions in a clinical orthodontic patient population.
Materials and methods: Patients treated in an orthodontic department (University of Pécs, Pécs, Hungary) were included. Unerupted teeth on panoramic radiographs were analyzed for intracoronal radiolucent lesions. For each patient, the demographic data, jaw localization, number of unerupted teeth with pre-eruptive intracoronal resorption lesions, number of lesions per tooth, size and localization of pre-eruptive intracoronal resorption defects, affected tooth's surface, pulp involvement and ectopic position of the tooth with defects were recorded.
Results: In the 3,143 patients investigated, 55 teeth in 49 patients showed pre-eruptive intracoronal resorption lesions (subject incidence: 1.56%). The incidence on unerupted teeth was 0.25%. Pre-eruptive intracoronal resorption was significantly more common in mandibles (43 mandibular vs. 12 maxillary lesions) with an odds ratio of 12.84 (95% Confidence Interval: 5.19–31.74) and no gender differences were found ($p = 0.746$). The occurrence of pre-eruptive intracoronal resorption was highest in the youngest (7–10 years) mixed dentition status group ($p < 0.001$). Most of the lesions (44 of 55, or 80.0%) were localized in the dentin, occupying two-third or less of the dentin thickness. Only 12.73% (7/55) of the lesions were not localized on the occlusal surface. Of the lesions, 89.1% (49/55) showed no obvious size increase over an average follow-up of 36.4 ± 8.1 months.
Conclusions: Pre-eruptive intracoronal resorption may occur mainly in the mixed dentition stage in orthodontic patients. Careful and attentive radiographic evaluations may facilitate early detection and follow-up of the lesions' possible dimensional changes, especially when resorption influences orthodontic extraction therapy.

1. Introduction

A pre-eruptive intracoronal resorption (PEIR) is an asymptomatic, well-defined and radiolucent lesion within the coronal dentinal tissue of non-erupted teeth [1,2]. The lesion is located directly below the dentin–enamel junction, which was first described by Skillen

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in 1941 [3]. Its histological characteristic is that its lesions show soft tissue with similar spindle-shaped cells, resorption cells and fibrous connective tissue cells. Regarding the etiology, the most widely accepted hypothesis today is that resorptive cells, such as osteoclasts, multinucleated giant cells and chronic inflammatory cells, attack the dentin through the microperforation of the crown. In the pre-eruption phase, local damage affects the membrane covering the enamel and may allow penetration of resorption cells into the dentin before enamel maturation or close to the cementoenamel junction. Osteoclasts and chronic inflammatory cells can originate from the surrounding bone or undifferentiated cells from the developing dental follicle.

No correlation has been shown between PEIR and race, gender, medical conditions, systemic diseases, systemic factors, or use of fluoride supplementation. According to Seow, however, there is a connection between occurrences of PEIR and the ectopic positions of the teeth [4]. This is based on the loss of the integrity of the Nasmyth membrane, which is caused by abnormal local pressure outside the position of the affected tooth germ or adjacent teeth, which initiates resorption [4,5].

The defect is mostly located in the mesial or central parts of the crowns of the premolar or molar teeth. The pulp is rarely affected, and clinically, the crown appears to be intact [6,7]. In some cases, the pulp can be affected in a short time, which leads to the development of a dental abscess [8]. Research suggests that the subject prevalence of PEIR in different countries is 0.2–27.3%, while that of tooth prevalence is 0.2–3.5% [9]. According to Seow et al. these lesions are found in 3% − 6% of the population and 0.5%− 2% of teeth. Most PEIR defects are found in the permanent dentition, and the mandibular first molar and maxillary first molar are mainly affected [1]. In Özden and Acikgoz's research, lesions were detected in 25% of lower jaws, while PEIR defects were discovered in a higher proportion (75%) of upper jaw areas. Based on their survey, only one tooth per individual was affected in 96% of cases. Of the teeth exhibiting PEIR defects, 14.3% were ectopically located [10]. In Al-Tuwirqi and Seow's study, the prevalence of impaction was 31% in teeth with PEIR lesions and 0.1% in teeth without these lesions [11].

Currently, no protocol is available for treating PEIR. Suggested options include restoration of the defect, root canal treatment and extraction. In cases classified as static (nonprogressive), most authors recommend the conservative approach of monitoring the lesion until eruption occurs [12–15]. Restoration of the tooth is necessary after the tooth has erupted. In cases classified as progressive (developing), immediate treatment is justified to avoid complications [16]. If the eruption of the tooth is not yet expected but the detected lesion is large, a flap elevation and curettage of the defect with a manual instrument may be justified [17,18]. In the case of pulp exposure, pulp covering and glassionomer cement restoration are the correct therapies. If the lesion is extensive or causes symptoms, extraction is the appropriate therapy [9].

One of the most popular, inexpensive, and relatively low radiation diagnostic methods in current use is the orthopantomogram (OP), which formed the basis of our examinations. One of the cornerstones of orthodontic diagnosis is taking a panoramic radiograph. Radiographs taken between multiphase orthodontic treatments also provide an opportunity to monitor the prognosis of the lesion.

Accurate evaluation of the radiological findings of non-erupted teeth can facilitate the early recognition and treatment of PEIR defects. Early detection is essential for inhibiting the progression of resorptive lesions. In most cases, these lesions are discovered by chance during routine X-ray examinations. The lesion is often only in the dentin, but in more advanced forms, the enamel is also affected. The panoramic X-ray is preferred for examination, as it requires less cooperation in the case of children and shows more unerupted teeth. The disadvantage is that the anterior region cannot be evaluated perfectly. Nowadays, cone beam computed tomography (CBCT) proves to be the most accurate alternative. However, based on the experience so far, bitewing, periapical and panoramic imaging can be used to confirm the diagnosis and monitor the progression [7,12,19–21].

The aim of this study was to determine the prevalence and characteristics of PEIR among patients applying for orthodontic care, since a large number of panoramic images can be found among this patient population. Further aim was to shed light on the clinical significance of PEIR for orthodontists, who might be in the first line as experts to discover this lesion based on radiological investigations.

2. Materials and methods

This cross-sectional retrospective study was performed in the Department of Orthodontics, in the Medical School of the University of Pécs, in Pécs, Hungary. The study sample consisted of 3,143 patients treated for orthodontic reasons. The study was approved by the Regional Research Ethical Committee of University of Pécs Medical School (No. 7920_PTE_2019). Informed consent was obtained from patients for publication of their clinical data.

Patients with an established orthodontic treatment plan based on physical examination, radiographic and model analysis were included. Patients with amelogenesis, dentinogenesis imperfecta, and any known systemic bone diseases were excluded from the study.

Each patient had at least one digital panoramic radiograph taken. All radiographs were taken by the same technician using standardized criteria. The panoramic radiographs were taken with a PaX-400C unit (10.42 line pairs/mm, 73 kV, 10 mA; authors' calculated magnification rate: 123.7% ± 6.4%) (Vatech, Gyeonggi-do, Korea). At least one unerupted tooth was required to be evident in the digital panoramic radiograph, without any significant image distortion, for inclusion in this study. Three experienced observers (DB, AP, and MF) analyzed the images. The ambient light and monitor used (high resolution, 19″ in size) were constant. For panoramic radiographic image analysis, Ezdent (Vatech) software was employed.

Clinical findings (pain or discomfort related to teeth) and demographic variables (sex, age) were recorded. The following radiographic parameters were analyzed: 1) number of unerupted teeth showing PEIR lesion/s, 2) number of PEIR lesion per tooth, 3) size and localization of PEIR defect(s), 4) affected tooth surface, 5) pulp involvement, 6) ectopic position of the tooth with the PEIR defect.

An unerupted tooth was assigned as one that was covered by bone and/or mucosa and below the occlusal plane [12]. To record the

PEIR size and intra-tooth localization, the new classification of Yüksel et al. was applied [22]. In our opinion, this classification provides the most accurate description of radiolucent lesions, since it considers enamel, dentine, pulp, and root region involvement. Using this new system, all the lesions were scored with a number between 1 and 15 [22]. A score of 1 indicates an isolated enamel defect, a score of 2–4 indicates an isolated dentine defect, a score of 5–7 indicates a combined enamel and dentin defect, a score of 8–10 indicates a combined dentin and root defect, a score of 11–13 indicates a complex enamel–dentin–root defect, a score of 14 indicates an isolated root defect, and a score of 15 indicates a combined enamel and root defect without dentin involvement. When either dentin or root is involved, a higher score is indicative of a larger defect (i.e., less than 1/3, less than 2/3, or more than 2/3 of the dentin or root thickness).

By analyzing the affected tooth surfaces, the defects were categorized as mesio-aproximal, mesio-occlusal, centro-occlusal, disto-occlusal, or disto-aproximal. Pulp involvement was diagnosed as PEIR radiolucency superimposed on the radiolucency of the pulp chamber.

A tooth was categorized as ectopically positioned if its longitudinal axis or the position of the crown deviated from the normal on the radiograph [23]. The ectopic situation was determined by taking into account the clinical judgment and agreement of an orthodontist and an oral surgeon.

2.1. Statistical analysis

For statistical analysis, MedCalc software was used (Version 20.2; MedCalc Software Ltd., Ostend, Belgium). To examine the occurrence of different PEIR characteristic factors and patient sex, Fisher's exact test, the χ^2 test, and an odds ratio calculator were used. To estimate the observer's reliability, Cohen kappa (κ) statistics were applied ($\kappa < 0.40$ indicated poor agreement, $\kappa = 0.40-0.59$ indicated fair agreement, $\kappa = 0.60–0.74$ indicated good agreement, and $\kappa = 0.75 - 1.00$ indicated excellent agreement). A p value ≤ 0.05 was considered significant.

3. Results

Of the 3,143 patients involved in this study, 1,697 were female (54%) and 1,445 were male (46%). The patients ranged in age from 7 to 22 years (mean: 15.8 ± 2.4 years). Overall, the patients had 22,144 non-erupted teeth based on the panoramic radiographs. PEIR lesions were found in 49 patients (26 female, 23 male), with a patient prevalence of 1.56%. The mean age of patients with PEIR defects was 14.8 ± 2.1 years. In the 49 patients affected by PEIR, six (12.24%) had PEIR in more than one tooth, resulting in 55 teeth overall being affected by PEIR lesions. Hence, the incidence among all unerupted teeth in the evaluated patients was 0.25% (55/22,144).

Table 1 shows the incidence of PEIR among the patients by age and the distribution of lesions in the jaws and teeth. The results clearly show that PEIR in the maxilla was found only in premolars and in canines. All the maxillary PEIR cases were from the mixed dentition period between seven and ten years. In the same age group, however, nine premolar and 5 M teeth were affected in the mandible. In the older age groups, PEIR lesions were found only in the mandible. In the 11–15-year-old group, 4 M and one premolar were affected by PEIR lesions, while in the permanent dentition group (16–22 years), only 2 M were affected by PEIR lesions.

In the male patients (Table 1), maxillary PEIR lesions were found only in five premolar teeth in the youngest group (7–10 years), while molars, premolars, and canines were affected in the mandible. In the older age groups, the occurrence of lesions decreased; in the 16–22-year-old male group, only two PEIR lesions were found.

PEIR was not present in canines in the 11–15-year-old male group. Considering the occurrence of PEIR in the examined age groups, the most PEIR defects were found in the youngest (7–10 years) group, and the result was statistically significant (39/55 cases; $p < 0.001$).

Considering all the cases, PEIR was more common in the lower dental arch (43 mandibular vs. 12 maxillary lesions). The odds for a mandibular occurrence of a PEIR lesion (vs. maxilla) were calculated to be 12.84 (95% confidence interval [95%CI] = 5.19–31.74). There was no statistically significant difference between males and females in terms of mandibular and maxillary occurrences (21/7 in males and 22/5 in females; $p = 0.746$). Furthermore, the occurrence of PEIR lesions in canines were similarly infrequent in both sexes

Table 1
Disposition of affected teeth by location according to age in this study.

Gender	Age group (years)	Affected tooth type (n)												Total
		Maxilla						Mandible						
		Molar			Premolar		Canine	Molar			Premolar		Canine	
		1st	2nd	3rd	1st	2nd		1st	2nd	3rd	1st	2nd		
Female	7–10	0			3	1	1	1	5	0	3	6	0	20
	11–15	0			0		0	0	3	1	0	1	0	5
	16–22	0			0		0	0	0	2	0		0	2
	Total	**0**			**4**		**1**	**12**			**10**		**0**	**27**
Male	7–10	0			2	4	0	0	4	7	1		1	19
	11–15	0	1	0	0		0	1	3	1	2	0	0	8
	16–22	0			0		0	0			0		1	1
	Total	**1**			**6**		**0**	**16**			**3**		**2**	**28**

(2/28 vs. 1/27; $p = 1.000$). Interestingly, no cases were found in incisors.

Based on the classification of Yüksel et al. [22], lesions scored as 2 or 3 were the most frequent (44/55 = 80.0%) among the PEIR lesions, without any sex dominance observed (Table 2).

When the localization of the PEIR lesions was analyzed (Table 3), it was found that occlusal tooth surfaces were the most frequently involved ($n = 48/55$). It was also found that there was no difference in the frequency between female (22/48) and male (26/48) patients ($p = 0.414$).

Mesio-occlusal (15/55 = 27.27%) and centro-occlusal (29/55 = 52.72%) appearances were the most frequent in both sexes. Pulp involvement was observed in four cases, and these lesions were scored between 4 and 9 in the classification of Yüksel et al. [22]. In 19 of the 55 (34.55%) cases, the tooth exhibiting PEIR was in an ectopic position. Of the 19 teeth, 14 were in buccal and 5 were in lingual ectopic position. In these cases, any obvious pressure effect by adjacent teeth, supernumerary teeth or e.g., odontomas were not assumed by the observers.

In all our cases, more than one panoramic radiograph was available due to the specialty of the orthodontic treatment group. Therefore, it was possible to follow-up the lesions and assess the static (no change in size) vs. dynamic (growing lesion) characteristics of each lesion. Most (89.1%; 49/55) of the lesions were static in nature (i.e., no obvious increase in size, based on the evaluators' decisions) over an average follow-up of 36.4 ± 8.1 months. Furthermore, in 23 cases, lesions appeared during the long orthodontic treatment and follow-up; the initial panoramic radiographs were negative for PEIR defects. An interesting case that exhibited this phenomenon is presented in Figs. 1–5.

In a 10-year-old male patient with an early mixed dentition period, no signs of PEIR could be detected on the panoramic image used for routine orthodontic diagnosis (Fig. 1).

Three years later, the physiological tooth change process could be clearly observed on the control panoramic image; however, radiological signs of PEIR on the left lower canine were still not visible (Fig. 2).

When the patient was 14 years old, a procedural panoramic image was taken after extraction of the bilateral upper first premolars and before applying fixed orthodontic devices and treatment (Fig. 3). According to the treatment plan that was based on earlier model and cephalometric analyses, sufficient space would be available for the lower left canine without premolar extraction.

When the patient was 16 years old, extensive intracoronal resorption was observed on the control radiograph (Fig. 4) taken during fixed orthodontic therapy. Despite sufficient space being created for the canine, spontaneous eruption of the tooth did not occur due to coronal destruction. On clinical examination and probing, the mucosa was completely closed above the tooth, and there was no evidence of communication to the lesion.

CBCT was performed to determine the appropriate therapy for the canine (Fig. 5). Due to the extensive PEIR lesion present, after consultation with the patient and their parent, extraction therapy was chosen, with later implant placement.

The intra-observer reliability was found to be good for the three observers (0.64, 0.66, 0.74), while the inter-observer's reliability was found to be good during this study (0.69).

4. Discussion

While there are several hypotheses for the etiology of PEIR, it is indisputable that local factors play an important role. Early clinical detection, however, is extremely important, because after eruption, caries can rapidly develop in the existing lesion [12,24].

In our study, there was no detectable difference in the occurrence of PEIR between the sexes. Of the 49 patients diagnosed with PEIR, 26 were female and 23 were male. This finding is in alignment with those published in the literature to date. In contrast, significant differences have been observed in terms of the average age of patients diagnosed with PEIR. In an analysis of 1,571 panoramic images (mean age = 8.72 ± 2.5 years), Al-Batayneh et al. found that patients with mixed dentition had the highest prevalence (89%) of

Table 2
The distribution of lesion size and tooth localization in the study groups according to Yüksel et al. [22].

Location of lesion	Score	Lesion (n)		
		Female	Male	Total
Enamel	*1*	0	0	0
Dentin <1/3	*2*	16	17	33
Dentine 1/3-2/3	*3*	6	5	11
Dentine >2/3	*4*	3	3	6
Enamel and dentin <1/3	*5*	0	1	1
Enamel and dentin 1/3-2/3	*6*	1	0	1
Enamel and dentin >2/3	*7*	0	1	1
Dentine and root <1/3	*8*	0	0	0
Dentine and root 1/3-2/3	*9*	1	1	2
Dentine and root >2/3	*10*	0	0	0
Enamel, dentin and root <1/3	*11*	0	0	0
Enamel, dentin and root 1/3-2/3	*12*	0	0	0
Enamel, dentin and root >2/3	*13*	0	0	0
Root	*14*	0	0	0
Enamel and root	*15*	0	0	0
Total		**27**	**28**	**55**

Table 3
Occurrence of pre-eruptive intra-coronal lesions in different tooth surfaces.

	Affected tooth surface				
	MA	*MO*	*CO*	*DO*	*DA*
Gender					
Female	1	8	12	2	3
Male	1	7	17	2	2
Total	**2**	**15**	**29**	**4**	**5**

Abbreviations: MA, mesio-approximal; MO, mesio-occlusal; CO, centro-occlusal; DO, disto-occlusal; DA, disto-approximal.

Fig. 1. Early mixed dentition status of a 10-year-old male patient. Signs of primary crowding can be seen; however, there is no sign of pre-eruptive intracoronal resorption.

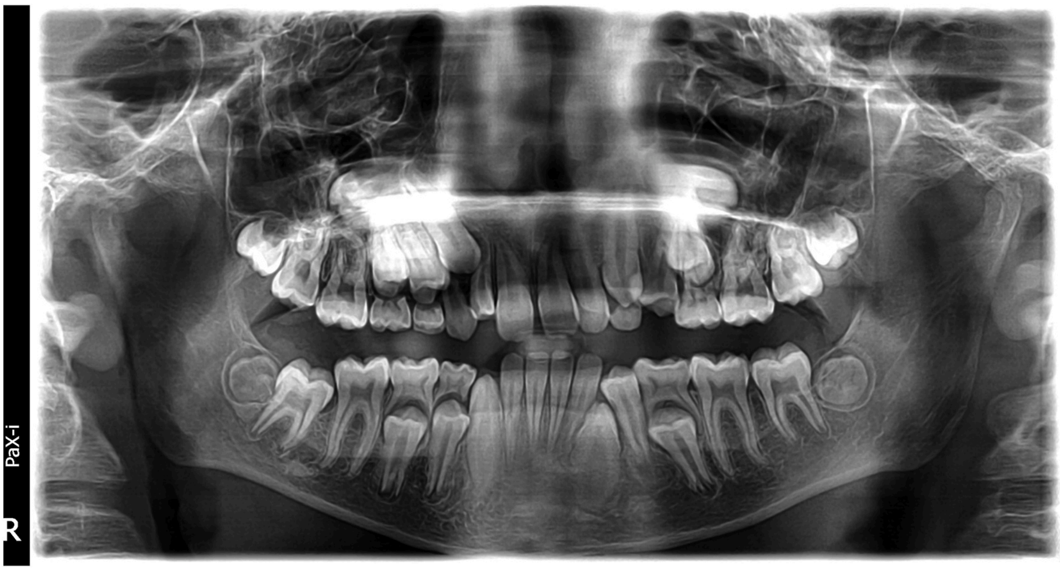

Fig. 2. The process of physiological tooth replacement is visible on the control panoramic radiographic image. No intracoronal lesions are evident.

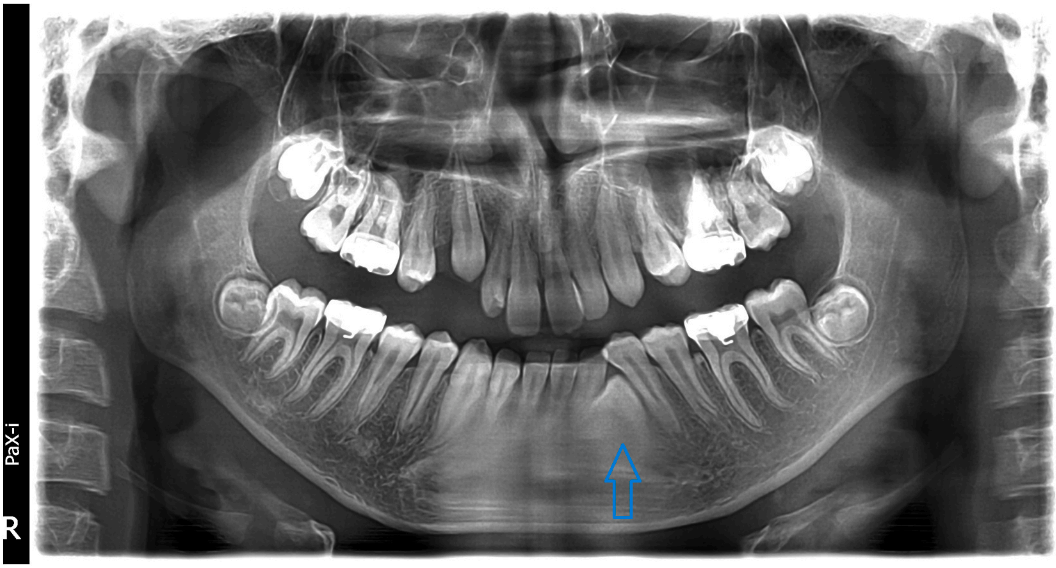

Fig. 3. At the start of orthodontic treatment, which began with extraction of the upper first premolar teeth. The impacted position of the left lower canine can be clearly seen on the x-ray image (arrow); however, the development of PEIR is not visible.

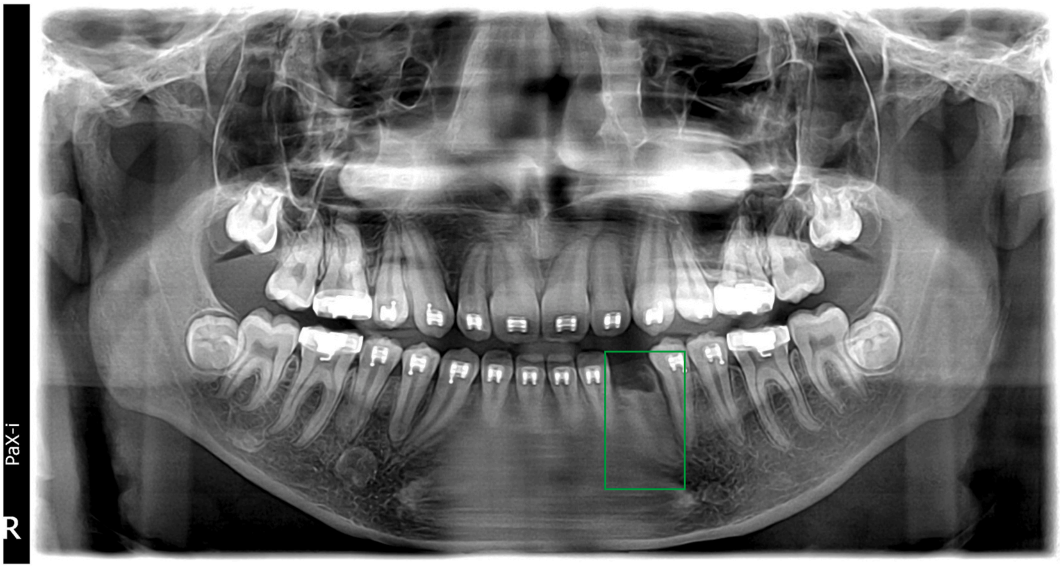

Fig. 4. Control panoramic image taken during orthodontic treatment. There are clearly visible signs of intracoronal resorption (cube).

PEIR lesions when primary and complete permanent dentitions were compared [19]. Seow et al. examined patients aged between 3.5 and 25 years and found a 3% subject prevalence [1]. Using the same method, Özden and Acikgoz analyzed the records of patients aged between 14 and 73 years and detected a subject prevalence of 1.55% [10]. Uzun et al. found a 0.7% subject prevalence when they analyzed data from a population aged between 18 and 72 years [12]. The probable reason for this is that the older the age group, the greater the chance that the molar teeth will remain in an impacted position. Seow et al. already published in 1999 that abnormal pressure and positional disorder can be predisposing factors in the development of PEIR [4]. PEIR lesions in the present study were observed almost in one third of the cases related to ectopic tooth positions. In a recent study, all PEIR cases found in high-risk, bony impacted third molars, showed a significant rotated situation or ectopic position [25]. It is assumed that the pressure caused by bad tooth position can result in damage to the protective layer of the tooth. This can trigger dentin resorption, with easier entry of resorptive cells [1,6]. For this reason, a higher incidence (1.4%) of PEIR has been found in upper supernumerary teeth [10]. This finding was supported by the results of Seow and Acikgoz's retrospective studies in which 14% of the teeth diagnosed with PEIR were in an ectopic position [4,10].

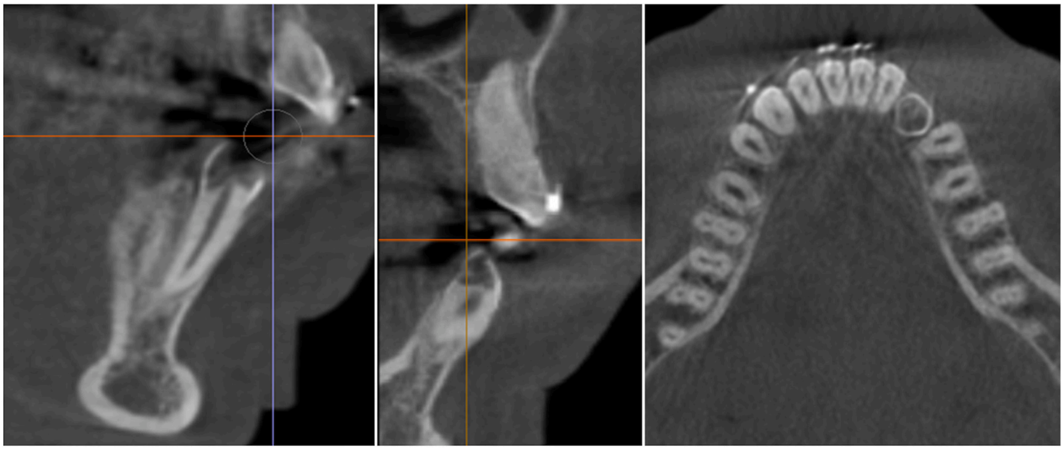

Fig. 5. The cone-beam computed tomography images showed a large, radiolucent, crown-destructing intracoronal resorption in the left lower unerupted canine. Neither radiological pulp involvement nor clinical symptoms were found.

In the present study, most of the examined patients had mixed dentition, and only one PEIR case was found in an impacted canine. In contrast, Asokan et al. found that the highest incidence of PEIR was in children under six years of age. They analyzed 5,012 panoramic images, and patients under 14 years were selected. Since there are still many unerupted teeth in children in this age group, there is a greater chance of early detection of PEIR [26].

In some studies, PEIR has been found to occur more frequently in the maxilla [10,22], while others have reported that it occurs more frequently in the mandible [4,16,27,28]. In the present study, significantly more lesions were detected in the mandible (43 lowers teeth out of 55 PEIR teeth), and mandibular dominance was observed similarly in both sexes.

Regarding the location of PEIR-affected teeth, significant differences have also been reported in the literature. Özden and Acikgoz reported that lesions most often occur in the mandibular second molar [10]. Al-Batayneh et al. found the highest PEIR ratio in the mandibular first premolar, and that PEIR was negligible in the area of the third molar [9]. Demirtas et al. reported that PEIR occurred most frequently in the maxillary molars, followed by the maxillary canines and mandibular molars [7]. In our study, we found that during the mixed dentition period, PEIR occurred most frequently in the area of the lower premolars (9 premolars out of 20 PEIR premolars) in female patients and in the lower molars (11 M out of 19 PEIR molars) in male patients. Differences in the results from different studies may originate from the difference in the average age of the examined populations and from the use of different radiological techniques.

When investigating the number of radiolucent lesions per teeth, it was obvious that single occurrence of lesion was more characteristic. Yüksel et al. in their study found 25 patients out of 164 examined with multiplex PEIR lesions [22], while in our study only six cases of multiplex abnormalities were found.

Several studies have found that PEIR 2 lesions are the most common defects; that is, defects in which intracoronal resorption is less than one-third of the dentin [13,21]. In our study, PEIR 2 and 3 lesions made up the largest proportion (44/55 = 80.0%) of the detected lesions. This finding is in accordance with those of Wang et al. [29], Konde et al. [30], and Nik et al. [31]. It is worth noting that several studies have described lesions larger than two-thirds of the dentin [4]. However, those studies included older age groups, and this may explain the appearance of more extensive lesions, as there was more time for the progression of the lesion. In a study conducted by Özden and Acikgoz, one of the highest occurrences (21.4%) of PEIR-affected teeth with scores of 4 was found [10].

Most of the PEIR lesions detected in our study were found on the occlusal surface (n = 48/55), which is similar to the finding of Omar et al. [32]. In several other cases, PEIR lesions have been detected on the mesial surface [1,30,31].

From a clinical perspective, the primary and critical factor is the correct diagnosis. Orthodontists have a considerable role in determining the diagnosis, since lesions are often revealed during orthodontic treatment. Previous studies have shown that panoramic imaging is sufficient for detecting PEIR lesions. When a more accurate assessment of localization, width, and extent is necessary, CBCT imaging is required [19]. A previous study that compared panoramic and intraoral radiographs confirmed that panoramic radiography is the correct technique for the diagnosis and monitoring of PEIR [7,27]. It is undisputed that intraoral radiographs provide greater accuracy in many cases; however, performing radiographs with a parallel technique is not always easy.

Bitewing and CBCT images generally result in a higher incidence (2% and 3.5%) of PEIR detection, and this can be explained by the fact that there are no overlapping structures [9,27]. Demirtas et al. found a considerably larger difference in their study: a subject prevalence of 3% was determined based on panoramic recordings, while a prevalence between 9.5% and 15.1% was found using CBCT imaging [7]. However, due to As Low As Reasonably Achievable (ALARA) principle, the lower radiation exposure of panoramic radiography should not be neglected [33]. To avoid unnecessary, repeated radiation exposure, it is recommended to take control radiographs at intervals of 6–12 months. When selecting the radiological technique to be used, the patient's age, cooperation, and other diseases (disabilities) must also be taken into account. To the best of our knowledge, an official recommendation for periodic control radiographs for monitoring PEIR has not yet been made. Of note, a nine-year follow-up study by Manmontri et al. demonstrated that lesion size did not change even after pre-eruption in the case of a tooth diagnosed with non-progressive (i.e., static) PEIR [34]. In the case of static lesions, an interrupted vascular supply from the external tissues surrounding the crown of the tooth may give some explanation for the static nature [17,35,36].

When lesions are considered to be small (score of 1–2), follow-up may be considered sufficient therapy. However, there is no agreement in the literature on the duration of the follow-up. Time intervals between six months and five years have been proposed. Several years of "waiting" may be contraindicated in terms of lesion progression; however, to prevent radiation exposure during routine radiography, it is recommended to perform radiological follow-up in accordance with the American Academy of Pediatric Dentistry (AAPD) guidelines [37].

When larger lesions (score of 2–4) are detected, treatment should be started even before the eruption of the tooth to protect the pulp. Damaged tissue can be removed using fine curettage with hand instruments [38,39]. In most cases, intervention involving a mucosal flap can be performed under local anesthesia [40]. For the direct closure of pulp exposure, some studies recommend the application of calcium hydroxide [18,40], while others recommend mineral-trioxid aggregates and Biodentine [41–43]. Grundy and Wood and Crozier et al. reported the successful treatment of cases using amalgam, following the application of zinc oxide eugenol [16,44]. Glass ionomer cement is also preferred for PEIR restorations [20,32,35,45]. When a PEIR-affected tooth has been severely damaged, it must be removed, and it is recommended to consult an orthodontist regarding the extraction and concurrent anodontia. If extraction therapy is required during an existing orthodontic treatment plan, then the treatment plan must be modified accordingly. If it is necessary to maintain the position of the missing tooth, the use of a space-maintaining device can prevent the later development of dental anomalies [38,46].

5. Conclusions

Routine orthodontic examinations provide an excellent opportunity for early detection of PEIR. The occurrence of PEIR was rare, (in ~1.56% of patients), and lesions were mainly observed in the mandible, frequently in ectopic teeth. Most of the PEIR lesions occurred on the occlusal surface and were found in the dentin, occupying less than two-third of the dentin thickness. However, PEIR lesions were dominantly (~90%) static in nature, regular orthodontic visits have the opportunity and might have the responsibility to observe dimensional changes.

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Ethical approval

The study was approved by the Regional Research Ethical Committee of University of Pécs Medical School (No. 7920_PTE_2019).

Author contribution statement

Zsuzsanna Gurdan: Contributed reagents, materials, analysis tools or data; Wrote the paper.
Dorottya Balázs; Dóra Pásti; Meetra Fathi,: Performed the experiments.
Peter Maróti; Kinga Kardos: Analyzed and interpreted the data.
Ana Pacheco: Conceived and designed the experiments.
József Szalma: Conceived and designed the experiments; Analyzed and interpreted the data; Wrote the paper.

Data availability statement

Data will be made available on request.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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