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Clinical and radiographic features of external cervical resorption – An observational study

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Abstract

Aim: To determine the prevalence of symptoms, clinical signs and radiographic presentation of external cervical resorption (ECR).

Methodology: This study involved 215 ECR lesions in 194 patients referred to the Endodontic postgraduate Unit at King's College London or Specialist Endodontic practice (London, UK). The clinical and radiographic findings (periapical [PA] and cone beam computed tomography [CBCT]) were readily accessible for evaluation. A checklist was used for data collection. Inferential analysis was carried out to determine if there was any potential association between type and location of tooth in the jaw as well as sex, age of the patient and ECR presentation and radiographic feature.

Results: Eighty-eight patients (94 teeth) were female and 106 patients were male (121 teeth), the mean age (±SD) was 41.5 (±17.7) years. Fifteen patients (7.7%) had more than one ECR lesion. The most affected teeth were maxillary central incisors (21.4% [46 teeth]) and mandibular first molars (10.2% [22 teeth]). ECR was most commonly detected as an incidental radiographic finding in 58.1% [125 teeth] of the cases. ECR presented with symptoms of pulpal/periapical disease in 23.3% [$n=50$] and clinical signs (e.g. pink spot, cavitation) in 16.7% [36 teeth] of the cases.
Clinical signs such as cavitation (14%), pink spot (5.1%) and discolouration (2.8%) were uncommon, but their incidence increased up to 24.7% when combined with other clinical findings. ECR was detected in the resorptive and reparative phases in 70.2% and 29.8% of the cases respectively.

Conclusion: ECR appears to be quiescent in nature, the majority being asymptomatic and diagnosed incidentally from PA or CBCT. When assessed with the Patel classification, most lesions were minimal to moderate in relation to their height (1 or 2) and circumferential spread (A or B). However, the majority of ECRs were in (close) proximity to the pulp. Symptoms and clinical signs were associated with (probable) pulp involvement rather than the height and circumferential spread of the lesion. Clinical signs were more frequently associated when ECR affected multiple surfaces.

KEYWORDS

clinical features, external cervical resorption, radiographic features

INTRODUCTION

External cervical resorption (ECR) usually manifests in the cervical aspect of teeth. ECR develops because of damage to, and/or deficiency of the periodontal ligament and the protective subepithelial cementum, it is a dynamic process that involves periodontal, dental and in later stages pulpal tissues (Luso & Luder, 2012; Mavridou et al., 2022).

The prevalence of ECR has been reported to be between 1.35% and 2.3% (Ferreira et al., 2022; Irinakis et al., 2020). ECR has attracted increased interest in the last two decades. This is in part due to a combination of improved radiographic detection with cone beam computed tomography (CBCT) (Mazón et al., 2022; Patel et al., 2009), novel micro-CT, histopathological assessment of ECR (Mavridou et al., 2016a, 2016b) and a better understanding of the potential aetiological factors (Mavridou et al., 2017). The increasing prevalence of ECR has resulted in the European Society of Endodontology (ESE) publishing a position statement on the diagnosis and management of ECR (ESE ECR position statement, 2018).

The diagnosis of ECR may be challenging, as well as the differential diagnosis with internal resorption and other types of root resorption (Gulabivala & Searson, 1995; Patel et al., 2023; Schwartz et al., 2010). Small and/or interproximal lesions may not be easily detected clinically compared to readily identifiable lesions which manifest themselves as extensively cavitated, cervical defects on approximal aspects of the tooth (Bergmans et al., 2002; Patel et al., 2009, 2023). In advanced cases, ECR presents with symptoms of (ir)reversible pulpitis and/or apical periodontitis; however, the prevalence of these presenting features is unknown. To date, there is no literature on the possible relationship between the presentation and the nature, severity and even tooth group of ECR.

It is well established that periapical radiographs (PA) have limitations for accurately diagnosing the presence and nature of ECR or even misdiagnosing it as internal root resorption. The use of CBCT has been shown to be more accurate for confirming radiographically the presence of ECR, and crucially the nature (apico-coronal and circumferential) of the lesion. This information is essential to first determine the practicality of actively managing ECR, and secondly, serves a baseline for assessing the progression of untreated (watchful waiting) cases as well as recurrence in actively managed cases (Mavridou et al., 2022; Patel et al., 2018a).

Heithersay (1999) published one of the first extensive reviews on ECR, assessing 257 cases focusing on the prevalence of different radiographic presentations but not on the clinical presentation. Irinakis et al. (2020) and Mavridou et al. (2022) assessed 98 and 313 ECR cases respectively. Both studies described the radiographic appearance and determined the provisional diagnosis of ECR; however, neither study described the prevalence or range of different presenting symptoms or clinical signs.

Heithersay (1999) classified lesions 1–4 based mainly on the apical extension of the ECR lesion on PA. The use of CBCT in endodontics has highlighted the under-reporting, misdiagnosis and under-estimation of the size of ECR lesions when assessed with PA (Mazón et al., 2022; Patel et al., 2016). An accurate assessment can only be made with PA when ECR is confined to the proximal aspect of a tooth. Lesions on the buccal or palatal/lingual surface cannot be readily and/or accurately assessed.

It is well established that the best clinical and scientific evidence is a combination and amalgamation of clinically relevant research and individual clinical expertise (Sackett et al., 1996). The limited clinical research on the clinical and radiographic presentation of ECR has been highlighted in the ESE ECR position statement (ESE ECR position statement, 2018). The majority of papers describing the presenting features of ECR are limited to narrative reviews and case (series) reports (Patel et al., 2018b). This has resulted in a paucity of knowledge on how ECR presents both clinically and radiographically, for example, what is the prevalence of clinical signs like a pink spot or cavitation? How common is it to see the reparative phase of ECR and/or is this phenomenon an age or specific tooth group phenomenon? A better understanding of the presenting features, and their prevalence is desirable to improve timely diagnosis as well as reduce the likelihood of misdiagnosis and should ultimately improve the longevity of the tooth.

The primary aim of this paper was to determine the prevalence of different symptoms, clinical signs and radiographic features of ECR. The secondary aim was to assess if tooth group and location or patient age and gender had an influence on the presentation of ECR.

METHODS AND MATERIALS

The clinical strategy in this study was in accordance with PROBE statement (Nagendrababu et al., 2020). This study was a retrospective, observational study of 215 ECR cases which were seen in the new patient Endodontic unit at King's College London or Endodontic specialist practice (London, UK) between September 2017 and January 2022.

Ethical approval was gained *Guy's and St Thomas' NHS Foundation Trust research and development committee** (08/H0804/79, 28/09/17).

Two experienced specialist endodontists assessed the clinical records of patients who had been previously diagnosed with ECR in non-root filled teeth to confirm the diagnosis after which an Excel spreadsheet (Microsoft®) was used to log relevant characteristics. Prior to the assessment of study data, the examiners were calibrated using radiographic data from 30 ECR cases which were not part of the experimental data set. The examiners unanimously agreed on confirmation of diagnosis, a consensus agreement was reached for determining the extent of the ECR and its nature as determined on PA and CBCT. Clinical data relating to the ECR, for example, tooth type, presenting symptoms, relevant clinical features (pink spot cavitation, sinus tract, etc.) and radiographic (PA and CBCT) features were recorded from the detailed, existing clinical records (Figure 1). The Patel (3D) classification based on the PR and CBCT findings was used to describe the nature of each ECR lesion (Patel et al., 2018c). All data were anonymized (Table 1).

Intraoral examination was carried out using loupes and/or a dental operating microscope. PAs were taken using a digital system with a paralleling technique and beam-aiming device (Rinn sensor holder XCP-DS; Dentsply Corporate). The X-ray unit (Nomad Pro 2; KaVo Dental Ltd) and PSP plates (Digora® [Optime; Soredex] or Planmeca Prostyle [Intra]); operating with digital CCD sensors (Schick Technologies) at 60 kV, 7.5 mA, 0.13–0.2 s was used. All PAs were scored as diagnostically acceptable.

CBCT scans were taken using a small volume CBCT scanner (3D Accuitomo 80; J Morita Manufacturing) with a 4×4 cm field of view, 0.08 mm of voxel size and 0.640 mm slice thickness set at 90 kV (tube voltage), 4–5 mA (tube current), and an exposure time of 17.5 s. CBCT scans were reformatted (0.125 mm slice intervals and 1.5 mm slice thickness).

Radiographic assessment

The PAs and CBCT (One-Volume Viewer, J Morita) were viewed on two large high-resolution screens (Radiforce MX270W; Eizo) in a quiet room with dimmed lighting, allowing the images to be assessed. To reduce examiner fatigue, only 30 cases were assessed in each viewing session.

Data analysis

A sample size calculation was carried out using G*Power software (version 3.1.9.6, Franz Faul; Christian-Albrechts-Universität Kiel). For a sample size of 180 patients, a power of 95% would be achieved to detect differences between two independent proportions, assuming a level of confidence of 95%. Descriptive statistics were carried out with SPSS software for Mac (version 28; SPSS Inc.) to assess data distribution. Absolute and relative frequencies for all variables were computed. Inferential analysis was carried out to determine if there was any potential association between the type and location of tooth in the jaw as well as sex, age of the patient and ECR presentation and radiographic feature. Chi-square test was used to compare the association between categorical variables or alternatively, Fisher's exact test to compare distribution among independent groups. The level of statistical significance was set to 5% ($\alpha = 0.05$).

RESULTS

Patients' distribution

In total, 194 consecutive patients (215 teeth) diagnosed with ECR were recruited into the study, 88 were female (94 teeth) and 106 were male (121 teeth). The overall mean (±standard deviation) age of patients was 41.5 (±16.5), females 42.7 (±17.7) and males 40.4 (±15.4). The age group distribution was: 16–30 years (30.2% [$n = 65$]), 31–45 years (29.8%, [$n = 64$]), 46–60 years (20.9% [$n = 45$]) and 61–81 years (19.1% [$n = 41$]).

Of the 194 patients, 15 patients (7.7%) had more than one tooth diagnosed with ECR, with a total of 36 teeth (16.7%) being affected. Of these, 12 patients had two teeth diagnosed with ECR lesions and three patients had set of four teeth affected (Table S1). Of the 12 patients with two teeth affected by ECR, 5 (41.7%) patients had multiple incisors affected. More male patients (66.7%, [$n = 10$]) had multiple teeth with ECR compared to female patients (33.3%, [$n = 5$]).

Teeth distribution

The most commonly affected tooth groups were incisors 40.5% ($n = 87$ [70 maxillary/17 mandibular]), molars 29.8% (64 [15 maxillary/49 mandibular]), canines 15.3% (33 [13 maxillary/20 mandibular]) and premolars 14.4% (31 [11 maxillary/20 mandibular]).

ECR was most associated with maxillary central incisors (21.4% [$n = 46$]) and mandibular first molars (10.2% [$n = 22$]). Overall, ECR was detected in 50.7% ($n = 109$) and 49.3% ($n = 106$) in the maxilla and mandible respectively (Figure 2).

Regarding the distribution of teeth with multiple ECR lesions, 44.4% were incisors ($n = 16$ [12 maxillary/4 mandibular]), 16.7% were canines (6 [2 maxillary/4 mandibular]), 16.7% were premolars (6 [2 maxillary/4 mandibular]) and 22.2% were molars ($n = 8$ [All mandibular]). No maxillary molars were affected by multiple ECR lesions in this study.

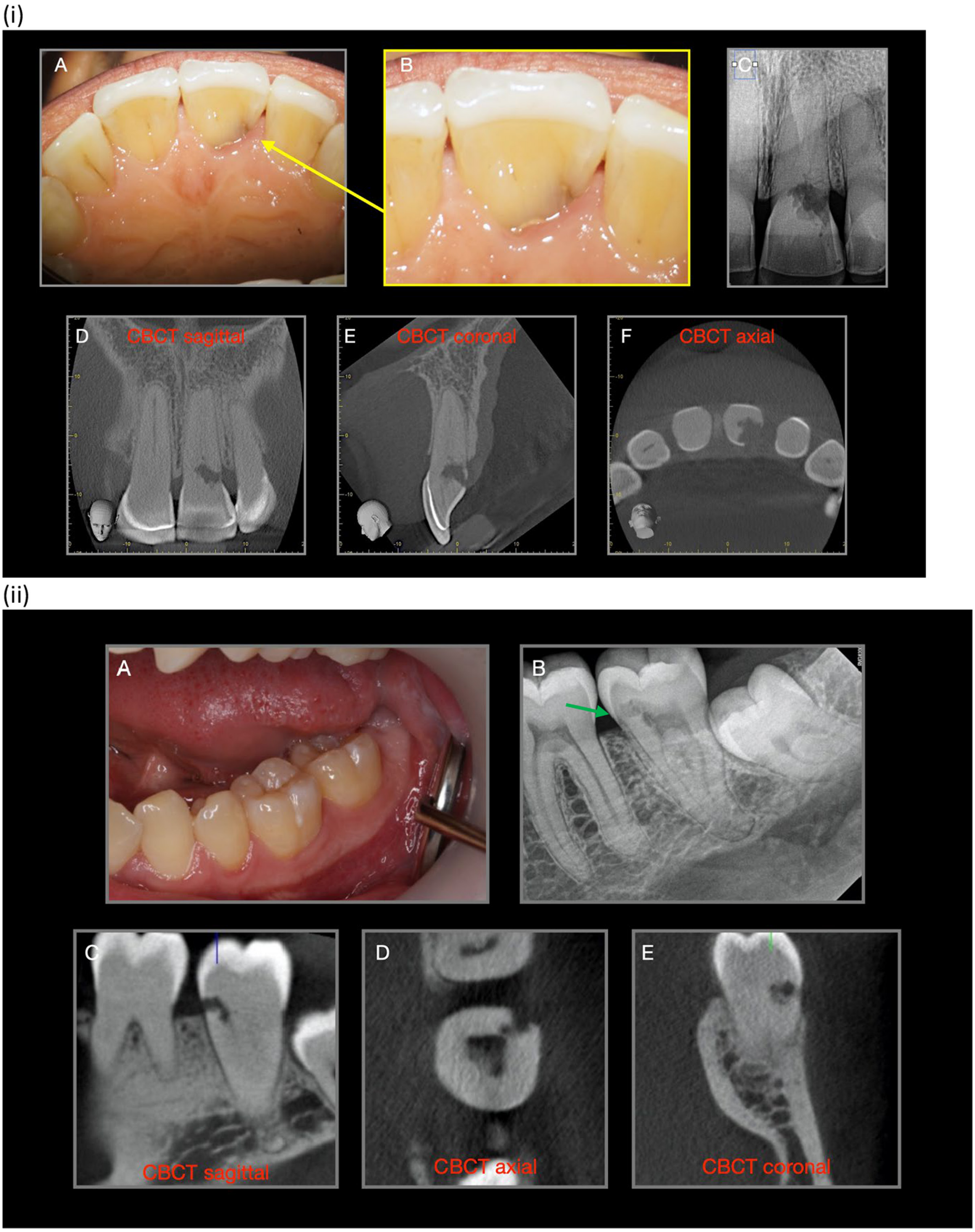
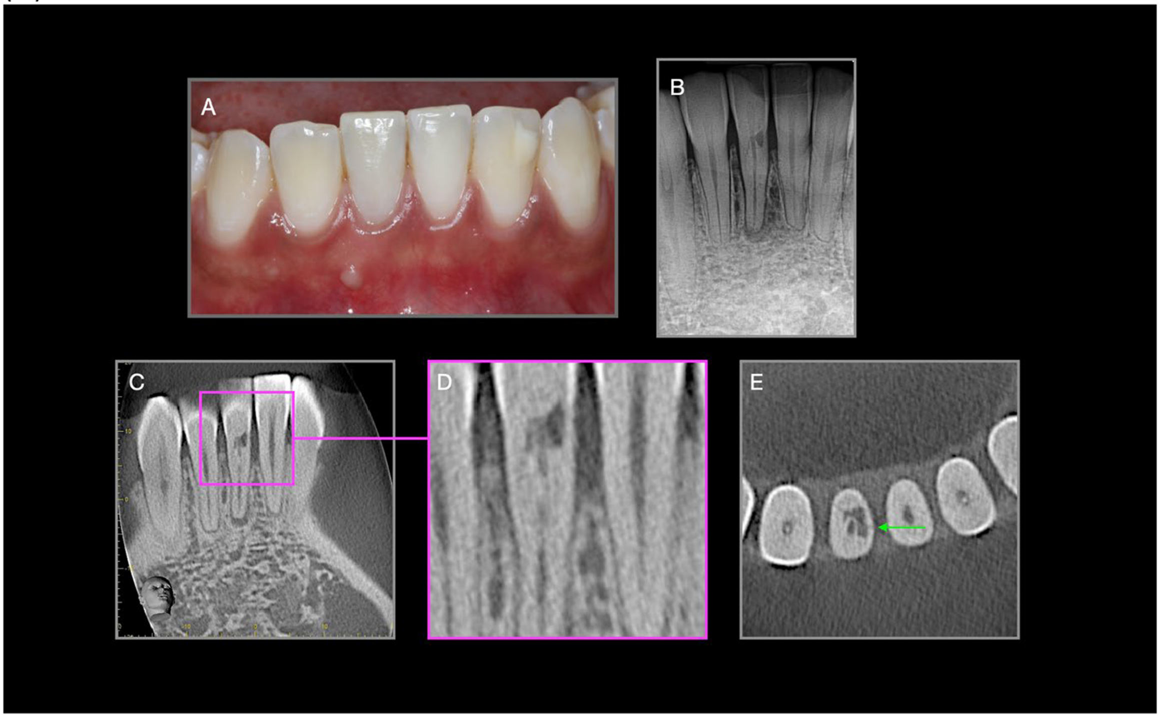


FIGURE 1 (i) Patel ECR 2Bp Asymptomatic upper incisor (A) clinical examination reveals subtle discolouration (yellow arrow) and subgingival cavitation, (B) PA confirms presence of ECR (yellow arrow). (D–F) sagittal, coronal and axial views reveal the nature of the ECR lesion. (ii) Patel ECR 1Bp Asymptomatic lower second molar with ECR which was an incidental finding when assessing unerupted, symptomatic wisdom tooth (A) clinical examination was unremarkable, (B) PA reveals ECR (green arrow), (C–E) sagittal, axial and coronal views confirm the nature of ECR. (iii) Patel ECR 3Bp Asymptomatic lower incisor (A) clinical examination reveals subtle abscess on the attached gingivae between 42 and 43 (B) PA confirms presence of ECR which appears confined to the mesial aspect only, however, (C–E) coronal and axial CBCT views reveal the apical spread into the mid-third region and into lingual aspect (green arrow), respectively. (iv) Patel 3Bp symptommatic upper incisor (A) radiograph reveals a radiolucency in the coronal third of the root, (B-C), (D,E) a series CBCT sagittal and coronal images showing the mixed nature of the lesion and the portal of entry (red arrow).

(iii)



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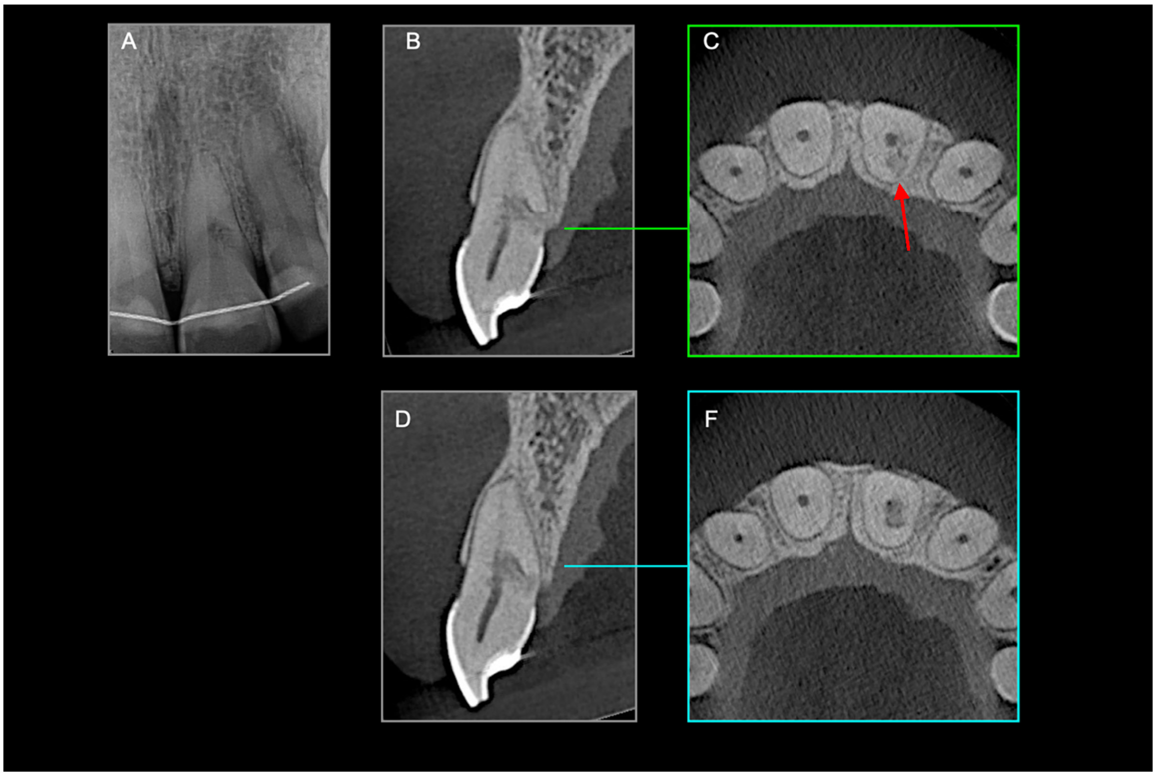


FIGURE 1 (Continued)

Initial presentation of ECR

In 58.1% (n = 125) of the cases, ECR was detected as an incidental finding on PA (38.6%) and CBCT (19.5%) respectively. The incidental finding of ECR on PA was significantly different between male (32.2%, 39/121 teeth) and female (46.8%, 44/94 teeth) patients (p = 0.029). In 23.3% (n = 50) of cases (Figure S1), the patient first presented

TABLE 1 Overview of the characteristics of ECR cases.

Tooth number (FDI)	
Patient sex	
Patient age	
Initial detection	Symptoms: Hypersensitivity, reversible pulpitis, irreversible pulpitis, apical periodontitis, abscess
	Incidental finding (PAs)
	Incidental finding (CBCT)
Clinical presentation	Nothing
	Cavitation
	Pink spot
	Sinus tract
	Periodontal pocket
	Discolouration
CBCT	
Number of tooth surfaces affected	1, 2, 3, 4
Location	Buccal
	Palatal/lingual
	Mesial
	Distal
Patel classification	1: At cemento-enamel junction level or supracrestal
	2: Extends into coronal-third of the root subcrestal
	3: Extends into middle third of the root
	4: Extends into apical-third of the root
	A: ≤90°
	B: >90° to ≤180°
	C: >180° to ≤270°
	D: >270°
	Limited to dentine or (probable) pulp involvement
Type	Destructive
	Reparative

with symptoms of pulp and/or periapical periodontitis, and a further 16.7% ($n=36$) presented with clinical signs (e.g. pink spot, cavitation, discolouration) (Figure 3).

A significant trend was observed between clinical signs associated with ECR and tooth type ($p=0.011$). Clinical signs were noted in 25.3% (22/87 teeth) of incisors, 18.2% (6/33 teeth) of canine, 16.1% (5/31 teeth) of premolars and only 4.7% (3/64 teeth) of molars. No significant association was found between initial detection of ECR and age of patients ($p=0.943$).

Symptoms and clinical signs in teeth affected by ECR

The distribution of the presenting symptoms associated with the ECR cases were chronic apical periodontitis (46%, 23/50 teeth), irreversible pulpitis (42%, 21/50 teeth), hypersensitivity (4%, 2/50 teeth), reversible pulpitis (4%, 2/50 teeth) and chronic apical abscess (4%, 2/50 teeth).

Cavitation (14%, $n=30$) was the most common clinical sign, followed by the presence of clinical symptoms (10.7%, $n=23$), pink spots (5.1%, $n=11$), discolouration (2.8%, $n=6$) and periodontal probing >5 mm (1.9%, $n=4$) (Table 2). Concerning multiple clinical presentations, the most frequently occurring combinations were pink spot with cavitation (6%, $n=13$), symptoms with cavitation and increased periodontal probing (3.7%, $n=8$), and pink spot with symptoms (2.8%, $n=6$).

The presence of symptoms in combination with other clinical signs was 23.3% ($n=50$), for cavitation it was 24.7% ($n=53$), for pink spot it was 14.9% ($n=32$) and for increased periodontal probing it was 9.8% ($n=21$).

There was a significant difference in the association between cavitation, as a clinical finding, and tooth type ($p=0.006$). ECR cases with cavitation were most often detected in canines (42.4%, 14/33 teeth), incisors (33.3%, 29/87 teeth), premolars (25.8%, 8/31 teeth) and molars (12.5%, 8/64 teeth). Canines were more frequently symptomatic (33.3%, 11/33 teeth) compared to molars (25%, 16/64 teeth), premolars (22.6%, 7/31 teeth) and incisors (18.4%, 16/87 teeth).

A pink spot affected incisors (19.5%, 17/87 teeth), canines (12.1%, 4/33 teeth), premolars (6.5%, 2/31 teeth) and molars (14.1%, 9/64 teeth), and overall was more commonly seen in the upper teeth (19.3%, 21/109 teeth) than lower teeth (10.4%, 11/106 teeth) ($p=0.067$).

Discolouration was most observed in ages between 31 and 45 years old (12.5%, 8/64 teeth) in comparison to the other age groups ($p=0.077$). Age had no significant association with the other clinical findings in teeth affected by ECR.

Radiographic presentation

Radiographic signs of ECR were detected in 83.3% ($n=179$) of the cases with PA, more cases were detected in maxillary (88.1%, 96/109 teeth) than in mandibular teeth (78.3%, 83/106 teeth) ($p=0.055$). All cases had a CBCT which confirmed the presence of ECR.

When the location of ECR was assessed with CBCT, the number of surfaces affected by ECR was: one surface (51.2%, $n=110$), two surfaces (27%, $n=58$), three surfaces (11.6%, $n=25$) and four surfaces (10.2%, $n=22$). Out of the 22 cases with all four surfaces affected, 77.3% ($n=17$) were single-rooted teeth and 22.7% ($n=5$) were multi-rooted teeth. ECR most affected the palatal (53.5%, $n=115$) and buccal (46.5%, $n=100$) surfaces while the mesial surface was the least commonly affected (40%, $n=86$) (Figure S2, Table S2).

FIGURE 2 Distribution of teeth according to the tooth type.

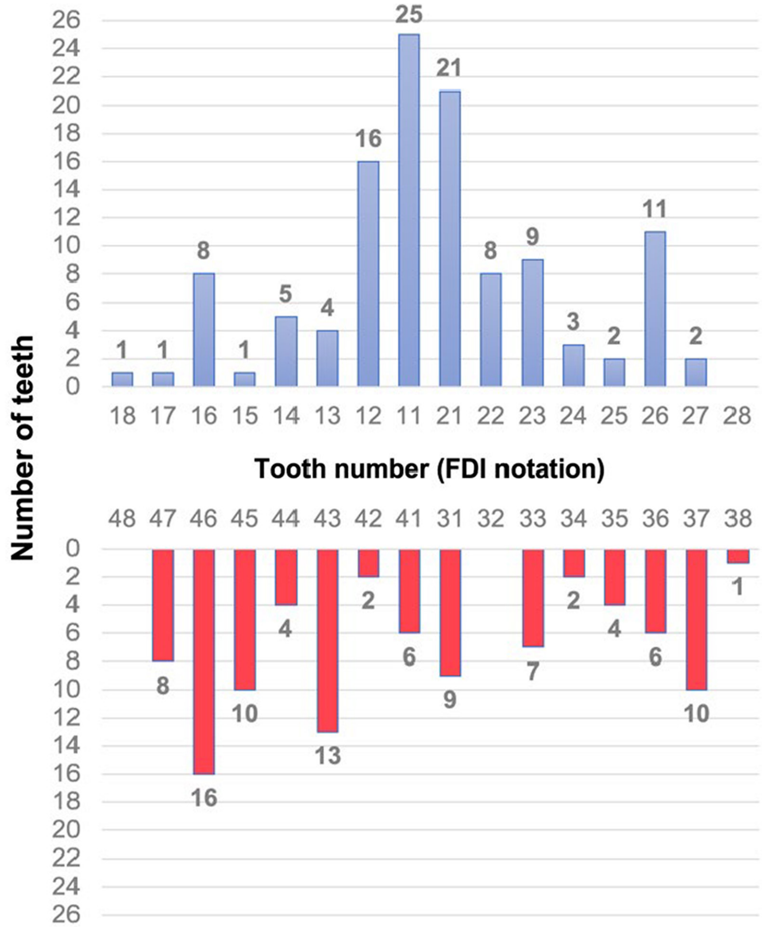
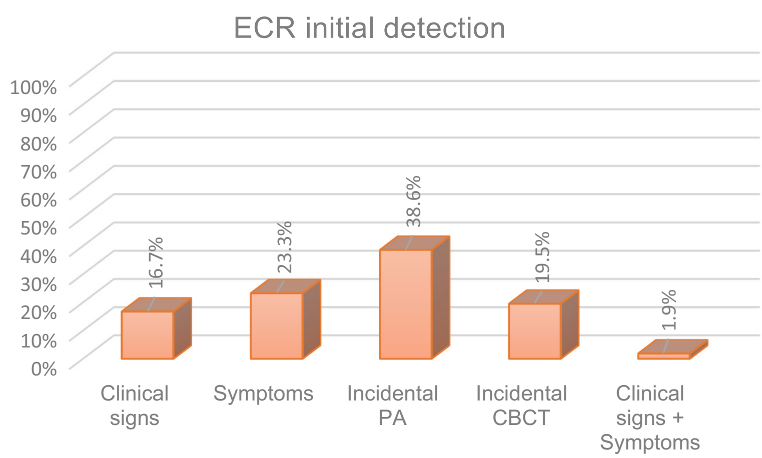


FIGURE 3 Percentage of each modality of ECR detection at the initial time of diagnosis.



ECR affecting four surfaces were more likely to be symptomatic (27.3%, 6/22 teeth) compared to three surfaces (20%, 5/25 teeth), two surfaces (24.1%, 14/58 teeth) and one surface lesions (22.7%, 25/110 teeth). Clinical signs were significantly ($p=0.048$) more frequently detected in multiple surfaces ECR lesions (21.9%, 23/105 teeth) compared to single surface lesions (11.8%, 13/110 teeth).

The frequency of appearance of ECR lesions on palatal location was significantly linked to gender ($p=0.022$), 60.3% (73/121 teeth) of male patients versus in 44.7% (42/94 teeth) of female patients (Figure 4). Palatal/lingual location of ECR was commonly found in canines (63.6%, 21/33 teeth) and least found in molars (37.5%, 24/64 teeth) (Figure 4).

Patel classification of ECR

The most frequent radiographic presentation were Patel 2Bp (17.2%, $n=37$), Patel 1Ad (12.6%, $n=27$), Patel 2Ad (8.8%, $n=19$) and Patel 2Ap (8.8%, $n=19$). Most of the cases had (probable) pulpal involvement (74%, $n=159$) (Figure 5).

ECR height showed a significant difference based on gender ($p=0.010$), with females, 46.8% (44/94 teeth) at level 2 (subcrestal) and 25.5% (24/94 teeth) at level 3 (mid-third), compared to 41.3% (50/121 teeth) and 28.9% (35/121 teeth) at level 2 and 3 in males, respectively (Figure S2). There was a significant association between the height of the ECR and the jaw location ($p=0.008$). In the maxillary teeth, 25.7% (28/109 teeth) were level 1 (supracrestal), 52.3% (57/109 teeth) were level 2 (subcrestal), 12.8% (14/109 teeth) were level 3 (mid-third) and 9.2% (10/109 teeth) were level 4 (extending into apical-third). Whereas in mandibular teeth, ECR tended to be more equally distributed in all four height levels (supracrestal, subcrestal, middle third and apical third of the root) (Figure S2).

TABLE 2 Clinical findings of ECR presenting with single and multiple findings.

Clinical findings	*n*	%
Pink spot	11	5.1%
Symptoms	23	10.7%
Cavitation	30	14%
Increased periodontal probing (localized)	4	1.9%
Discolouration	6	2.8%
Pink spot + symptoms	6	2.8%
Pink spot + cavitation	13	6.0%
Pink spot + cavitation + increased periodontal probing	1	0.5%
Pink spot + symptoms + cavitation + increased periodontal probing	1	0.5%
Symptoms + cavitation	8	3.7%
Symptoms + increased periodontal probing	8	3.7%
Symptoms + discolouration	3	1.4%
Symptoms + cavitation + periodontal probing	1	0.5%
Cavitation + increased periodontal probing	4	1.9%
Cavitation + discolouration	2	0.9%
Increased periodontal probing + discolouration	2	0.9%

There was a strong association between circumferential spread of the ECR lesion and gender ($p=0.052$). In male patients, the majority of ECR (46.3%, 56/121 teeth) were grade A (<90°), 27.3% (33/121 teeth) were grade B, 15.7% (19/121 teeth) were grade D (>270°), whereas grade C (180° to ≤270°) had the lowest incidence (10.7%, 13/121 teeth). In female patients, the highest frequency of ECR (41.5%, 39/94 teeth) was grade B (>90° to ≤180°), 29.8% (28/94 teeth) was grade A (<90°), 14.9% (14/94 teeth) was grade C (180° to ≤270°), whereas the lowest incidence (13.8%, 13/94 teeth) was grade D (>270°).

The majority of ECR showed closed proximity to the pulp or has perforated the pulp canal space. The older the patient, the highest the probability of pulp involvement ($p=0.018$). The incidence of probable pulpal

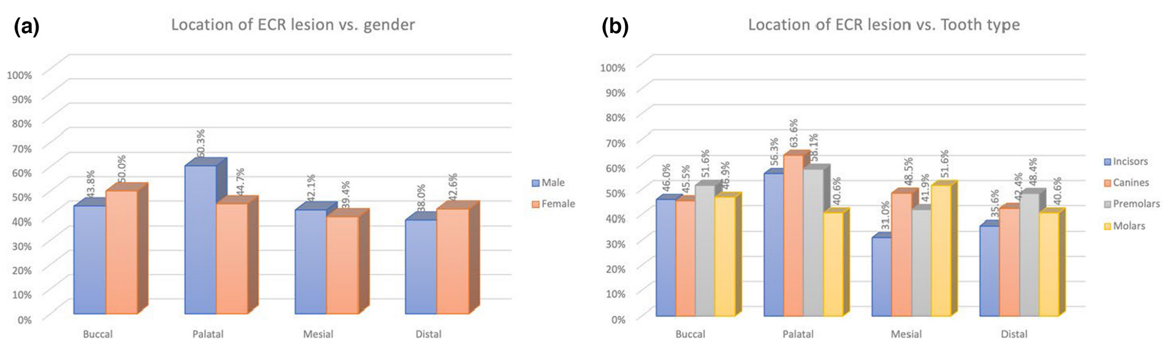


FIGURE 4 Association between the location of the ECR and (a) gender, (b) tooth type.

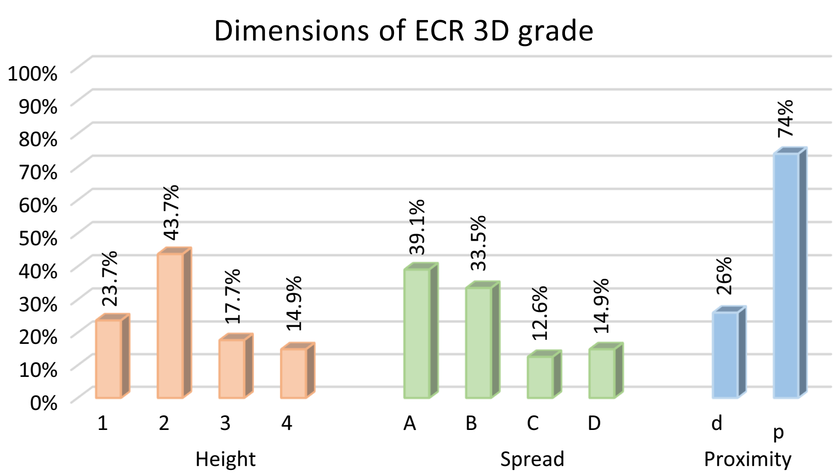


FIGURE 5 Bar chart showing the prevalence of the different scores for the 3D Patel classification for height, spread and proximity to the pulp of all analysed ECR lesions.

involvement varied between aged groups; 63.1% (below 30 years), 70.3% (31–45 years), 82.2% (46–60 years) and 87.8% (>61 years), conversely the incidence of the ECR lesion confined to dentine was 36.9% (below 30 years), 29.7% (31–45 years), 17.8% (46–60 years) and 12.2% (>61 years).

The presence of symptoms and clinical signs were not generally correlated with ECR's height and circumferential spread ($p > 0.05$), it was significantly associated with (probable) pulpal involvement ($p = 0.008$).

Stage of ECR

ECR was detected in the resorptive (destructive) and reparative phases in 70.2% ($n = 151$) and 29.8% ($n = 64$) of the cases respectively. Age had a significant influence on the type (destructive/reparative) of ECR lesion ($p = 0.027$). The highest percentage of destructive cases were observed above age 60 (85.4%, 35/41 teeth) and the lowest percentage was observed below the age of 30 years (60%, 39/65 teeth) (Figure 6).

DISCUSSION

To date, there is no literature assessing the association between the presentation, nature, severity and tooth group of ECR. To the authors' knowledge, this is the first study to systematically analyse the presenting symptoms as well as clinical and radiographic findings of ECR. The aim of which is to provide the clinician with a clearer insight into the prevalence of the presenting features of ECR. Previous clinical studies have only reported a partial analysis of the patient's symptoms, clinical signs and radiographic appearance (Irinakis et al., 2020; Mavridou et al., 2022; Nosrat et al., 2022).

The sample size of 215 teeth in this study improved the reliability and ultimately the significance of the results; 7.7% ($n = 15$) of patients had more than one ECR lesion, this equated to 36 teeth (16.7%). Previous observation studies found the incidence of multiple lesions ranged from 11.2% (32 of 284 patients) to 12.7% (15 of 118 patients) (DeLuca et al., 2023; Mavridou et al., 2017).

The mean age of presentation of ECR in this study was 41.5 years, which is similar to previous large cohort studies; 37 years (Heithersay, 1999), 37.9 years (Mavridou et al., 2017) and 40 years (Villefrance et al., 2022).

In agreement with Mavridou et al. (2017), the frequency of appearance of ECR was highest (30.2%) for young patients (<31 years) and lowest (19.1%) for older patients (>60 years). The wide age range highlights the importance of considering ECR as a provisional diagnosis regardless of age. The reason why ECR may not be so commonly diagnosed in older patient groups may be because any teeth with ECR may have been (previously managed) and/or subsequently extracted. This is reflected in the failure (and therefore extraction) rates of treated ECR lesions being 57.3% and 71.4% at 8 and 10 years, respectively (Mavridou et al., 2022).

The prevalence of ECR was higher in males (54.6%) than females (45.4%), Ferreira et al. (2022) also found a higher prevalence of ECR in males. In addition, there was a significant association between gender and incidental detection of ECR using PA ($p = 0.029$), ECR location on the palatal surface ($p = 0.022$) and height of the ECR lesion ($p = 0.010$). This higher incidence of ECR in males may be due to the higher prevalence of dental trauma in males compared to females (Bastone et al., 2000). In addition, multiple teeth affected by ECR were mainly diagnosed in males (66.7%, 10/15 patients), which agrees with a previous study (Jeng et al., 2020).

The present study revealed a significant association between the patient's age and the probability of pulp

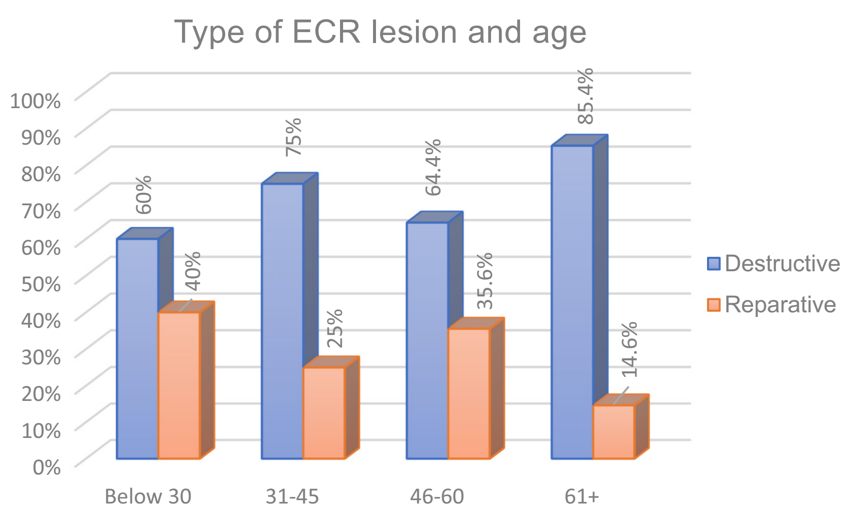


FIGURE 6 Association between the type of the ECR lesion and age.

involvement ($p=0.018$). Patients 46 years old or above had a greater possibility (82%+) of (probable) pulpal involvement. Previously published cohort studies have not assessed this relationship. Moreover, ECR lesions tended to show a more destructive nature in patients above the age of 60 years ($p=0.027$). This may be due to a change in the composition of mature dentine making it more susceptible to resorption (Montoya et al., 2015). ECR presented more commonly in patients under the age of 45, thus potentially slowly progressing and resulting in more eventual destruction the longer it is left undiagnosed. This may also be the reason why the likelihood of (probable) pulp involvement on initial diagnosis increases with age.

Overall, ECR was most often diagnosed in maxillary anterior (incisors/canines) teeth (55.8%); similar results were found by Mavridou et al., 2017 (52%), Irinakis et al., 2020 (57.1%), Jeng et al., 2020 (43.6%). This may be due to this tooth group being more easily visualized and/or thinner cortical plate resulting in earlier, incidental radiographic detection. It has also been suggested that high prevalence in this tooth group may be due to these teeth being more susceptible to dental trauma (Heithersay, 1999; Mavridou et al., 2017) and/or being potentially affected by an orthodontic treatment which are both well-recognized predisposing factors of ECR (Heithersay, 1999; Mavridou et al., 2017).

Maxillary central incisors (21.4%) were the most affected teeth, this concurs with previous cohort studies which also found that maxillary central incisors were the most affected teeth (Heithersay, 1999; Matny et al., 2020; Mavridou et al., 2017). Maxillary (9%) and mandibular (10%) first molars were the next most common affected teeth group. A previous observational study of 168 teeth also found that molar teeth were the second most common group after maxillary incisors to be affected with ECR (Matny et al., 2020). The relatively high incidence in molar teeth may be due to these teeth being one of the first teeth to erupt and therefore being exposed for a potentially longer time to potential aetiological factors such as parafunction (Mavridou et al., 2017).

Multiple ECR lesions mainly affected maxillary central incisors (33.3%, 12/36 teeth) and mandibular molars (22.2%, 8/36 teeth), whereas the least frequently affected teeth were maxillary canines and maxillary premolars (5.6%, 2/36 teeth).

One of the most striking features of this study was the relative infrequency of presenting symptoms (23.3%) in the 215 teeth affected by ECR, this compared to 48.4% of teeth being symptomatic on presentation in a study of 63 ECR cases by Jeng et al. (2020). In the present study, 83.3% presented with clinical or radiographic (PA) signs of ECR, and this is compared to 51.6% of teeth in the Jeng et al. study. Cavitation as a sole, or in combination with other symptoms and/or clinical signs was noted in 14% and 27.4%, respectively, and most affected anterior teeth. As mentioned in the aforementioned paragraph this may be due to the relatively easier visualization of the anterior teeth compared to posterior teeth and/or this tooth group is most commonly associated with dental trauma compared to premolar/molar teeth (Atabek et al., 2014). A pink spot as a sole and/or in combination with other symptoms and clinical signs was noted in 5.1% and 14.9% of cases, respectively, and was more commonly detected in maxillary incisors and mandibular first molars presumably as these teeth were most affected with ECR. This observation highlights that clinicians should not necessarily look for a pink spot when suspecting or confirming ECR. Symptoms and clinical signs were only associated with the proximity of ECR to the pulp, rather than the actual size of the lesion.

Localized increased periodontal probing was observed as a presenting feature in 1.9% as a sole and 9.9% in combination with other features, this compared to 50.8% of cases assessed in 63 teeth affected by ECR observed by Jeng et al. (2020). The breakdown of this feature being a sole or in combination with other presenting features was not mentioned in the aforementioned study, or if the increased periodontal probing was localized to the affected tooth or a generalized observation. It is difficult to contextualize the results in this study with the existing literature as previous observational studies have not comprehensively reported in detail the different presenting features. This is due to these studies having different aims, for example, assessing potential predisposing factors, tooth distribution and/or radiographic features (Irinakis et al., 2020; Jeng et al., 2020; Matny et al., 2020).

Despite the majority of ECR being in close proximity/perforated the root canal (74%) and/or resorptive (destructive) (70.2%) in nature, the majority of lesions were asymptomatic and/or had no clinical signs and commonly detected as an incidental radiographic finding. These findings are in agreement with those obtained by other studies (Irinakis et al., 2020; Nosrat et al., 2022). The quiescent nature of ECR may be due to the relative slow progression of ECR, the Pericanalar resorption-resistant sheet, formation of pulp stones and calcifications, hyalinosis, and/or an increased deposition of predentine preventing, or at least delay pulpal symptoms by 'insulating' the pulp from the resorptive front (Mavridou et al., 2016a).

In this study, the majority (58.1%) of the cases were detected as incidental radiographic findings with 38.6% being first detected on PA, and a further 19.5% being detected with CBCT. Overall, 83.3% of ECR cases were detected with PA, whilst CBCT confirmed the presence of ECR in all cases. CBCT may reveal 'hidden' lesions and/or confirm the presence of ECR which otherwise may be undetected or misdiagnosed (Mavridou et al., 2017).

Vaz de Souza et al. (2017) simulated a variety of different sized ECR lesions in human dry jaws and concluded that CBCT was accurate in diagnosing ECR than PA. In a clinical study assessing 115 teeth with ECR the overall sensitivity and specificity of PAs was significantly lower than CBCT, thus resulting in lower detection and poorer treatment planning of ECR with PA (Patel et al., 2016). CBCT for diagnosis and/or management is only justifiable when an ECR is detected or suspected after clinical examination and PA (ESE ECR position statement, 2018; Patel et al., 2023).

The Heithersay classification was designed to be used with PA only and in the only study to assess its accuracy was found to be only 48.5% accurate (Vaz de Souza et al., 2017). In another study, three calibrated evaluators independently assessed 168 ECR lesions, it was concluded that there was poor agreement between the evaluators when classifying the ECR with PA using the Heithersay classification (Matny et al., 2020). This classification was not used in the present study as the two-dimensional classification does not predictably reveal the nature of ECR on the non-proximal aspects or the depth of the lesion - these features can only be determined with CBCT (Ferreira et al., 2022; Mázon et al., 2022).

The Patel classification was used in this study as it provides a more accurate and descriptive assessment of the nature of ECR. It is anticipated that the Patel classification will facilitate a more objective assessment of treatment outcome (including watchful waiting) and prognostication in relation to the three-dimensional nature of ECR (Patel et al., 2023).

The majority of cases affected only 1 (51.2%) or 2 (27%) of surfaces, this may indicate the self-limiting nature of ECR. A similar trend was found by Irinakis et al. (2020). Matny et al. (2020) concluded that 65% of the cases they assessed had spread less than 180 degrees around the root. It may be hypothesized that the lower frequency of teeth with 3 and 4 surfaces affected may be partly due to these teeth becoming symptomatic and therefore being treated and/or extracted due to the poor prognosis of advanced ECR (Mavridou et al., 2022). In the present study, ECR affecting all four surfaces of the tooth tended to be single-rooted tooth (77.3%), this may be due to the lower root surface circumference to ECR ratio compared to the molar root surfaces. CBCT confirmed that ECR mostly affected the buccal or lingual surfaces of the root. It has been suggested that occlusal stresses transferred to the buccal/labial aspects of the tooth may result in a change in the composition and/or characteristics of the cementum in this region (Mavridou et al., 2022). The height of the majority of the cases (67.4%) were limited to the coronal-third of the root, similar results were found by Irinakis et al., 2020 (51%) and Matny et al., 2020 (46%). This may be due to the potentially self-limiting nature, early detection of ECR and/or that more advanced (untreatable) lesions may have become symptomatic and extracted.

A lesion was categorized as 'resorptive' (destructive) if the ECR lesion was radiolucent in nature, and 'reparative' if it was radiopaque, mottled or cloudy on PA and/or CBCT (Gunst et al., 2013; Iqbal, 2007; Patel et al., 2018a). The majority of the cases (70.2%) being resorptive (destructive) in nature may suggest that in this study the lesions were diagnosed relatively early, that is, before they could 'repair' themselves with bonelike (reparative) tissue and/or that the reparative phase is not as common.

The two examiners were experienced clinical academics with 40+ years' experience between them and worked as a consensus panel to assess the radiographic data. Both examiners had considerable experience in the interpretation of PA and CBCT, as well as in carrying out clinical research in both ECR and CBCT. This was particularly important with ECR as the diagnosis is so reliant on the radiographic interpretation of the lesion. Ideally, every tooth would have been treated or extracted and assessed histologically to confirm the diagnosis; however, this is not ethical or practical to do. Management of a significant portion of these teeth did confirm the diagnosis and nature of ECR. It is well established that consensus panels surpass the accuracy of individual expert diagnoses and has been used extensively in studies (Jones & Hunter, 1995). The use of a consensus panel has been used previously in studies assessing ECR lesions (Patel et al., 2009; Villefrance et al., 2023).

More awareness is required within the profession on the presenting features of ECR. Future studies are needed to assess the outcome of treated, as well as untreated teeth that are being reviewed on a periodic basis (watchful waiting), and to assess if there is an association between the nature of ECR on initial presentation and the prognosis of different treatment options.

CONCLUSION

ECR was more prevalent in males. The study highlighted that the presentation of ECR, clinically and radiographically varied widely; there were no 'classic', pathognomic features. Early diagnosis is essential to allow the patient to be informed of the existence of ECR and, if required to facilitate timely management. Clinical signs such as cavitation (14%), pink spot (5.1%) and discolouration (2.8%) were uncommon as sole signs, but their incidence increased when combined with other clinical signs. The most affected teeth were maxillary central incisors and mandibular first molars. A small portion of patients (7.7%) had more than one ECR lesion present.

This study confirmed the quiescent nature of ECR, with the majority of cases being asymptomatic and diagnosed incidentally from PA or CBCT. Most lesions were resorptive (destructive) in nature. When assessed with the Patel classification most lesions were minimal to moderate in relation to their height (1 or 2) and circumferential spread (A or B), however, the majority of ECR had (probable) pulp involvement. Symptoms and clinical signs were associated with (probable) pulp involvement rather than the height and circumferential spread of the lesion.

AUTHOR CONTRIBUTIONS

SP: conceptualization, methodology, visualization, resources, writing – original draft, writing – review and editing, project administration. FA, KP, NA-N: writing, resources, review and editing. PL: writing – review and editing.

CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

DATA AVAILABILITY STATEMENT

Data sharing is not applicable to this article as no new data were created or analyzed in this study.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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