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Case Report | **Dentistry**

Treatment of Teeth with Root Resorptions: A Case Report and Systematic Review

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Abstract

Aim. This article presents an evaluation of different multidisciplinary treatment approaches to managing teeth with external and internal root resorptions.

Methods. This study presents a clinical case of a 35-year-old female patient referred to Akdeniz University for dental issues. A comprehensive review of the literature was conducted, encompassing 21 articles sourced from PubMed and Web of Science over the past decade, including case reports and case series.

Results. ***Case Report.*** A clinical case of a 35-year-old female patient seeking treatment for dental aesthetic concerns was reported and discussed. Intraoral examination revealed discoloration of maxillary anterior teeth and a sinus tract in the apical region of tooth #11. The resorption area was sealed with mineral trioxide aggregate. Afterward, the coronal part of the root was filled using the warm-vertical compaction method. During the final visit, non-vital bleaching was applied to teeth #11 and #21. After all these procedures, aesthetic coronal restorations were completed. ***Systematic Review.*** In the context of this clinical case, a literature review was conducted, encompassing an assessment of a total of 25 cases of external and internal resorptions. Among these cases, a combination of surgical and endodontic treatments was applied in 12 cases, while non-surgical endodontic treatment was performed in 13 cases.

Conclusions. In the present case report, a patient who had both external and internal root resorptions was treated with mineral trioxide aggregate and flap operation, with no subsequent complications during the follow-up sessions. Among the 21 reports included in our review, 24 out of 25 treated teeth demonstrated successful outcomes, while only one tooth necessitated extraction.

Keywords

Internal Root Resorption; External Root Resorption; Tooth Resorption; Resorption Diagnosis; Resorption Treatment

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Introduction

Root resorption (RR) is a physiological or pathological process that results in the loss of dental tissues. There are various types of resorption affecting teeth and surrounding tissues. Each type has one or more specific etiologies, specific pathogenesis, and specific treatment protocols [1]. In permanent dentition, RR is caused by osteoclast-like multinucleated giant cells called odontoclasts. Unmineralized precementum and predentin layers protect the tooth against external and internal RR. There are different classifications of RRs based on histology, origin, etiology, and location [2] as well as resorption location, etiopathogenetic features, and radiographic observations (Fig. 1) [3].

Internal root resorption (IRR) starts along the root canal wall and may destroy intraradical dentine and dental tubules. It can progress and potentially result in root perforation, which can lead to lesion formation when the entire root canal system is infected [4]. RR is a common finding in teeth with infected necrotic root canals due to caries and microleakage [2]. External root resorption (ERR) occurs due to the activation of osteoclasts on the root outer surface and results in cement loss [5].

Although the etiology of RR is not precisely known, it

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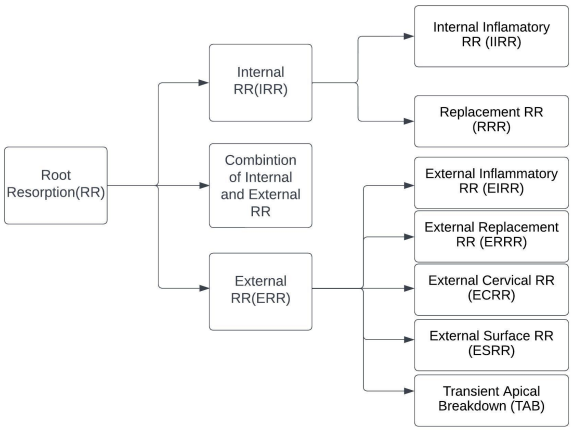

Figure 1. Detailed classification of root resorption [3].

may occur due to patient-related factors or iatrogenic conditions [3]. According to research, orthodontic treatment and previous traumatic injuries are the most common causes of RR [6]. In addition, tooth preparation for prosthetic purposes, vital pulpotomy, root resection, tooth cracks, and bleaching are some of the iatrogenic causes of RR [3].

Diagnosis and Treatment

Early diagnosis is the most critical step in RR management. The diagnosis is usually made based on clinical and radiographic examinations, as the absence of symptoms makes the diagnostic process more challenging [7]. In IRR, the destruction by resorbing cells can cause a pink discoloration on the crown, known as a 'pink spot'. When the pulp becomes necrotic, it turns gray [8]. The diagnosis can be confirmed radiographically. Generally, IRR lesions are defined as symmetrical radiolucent round to oval defects within the root canal walls [3].

Radiographic examination of ERR can reveal different features. In external surface RR (ESRR), it is common to see an asymmetric loss of external root surface. ESRR can occur due to orthodontic treatment. External cervical RR (ECRR) has no common radiographic features [1]. They may vary depending on the location, severity, and phase of the lesion. When the tooth is asymptomatic, it can be difficult to distinguish ECRR from IRR [4]. Two-dimensional parallax radiographs are commonly used to differentiate ECRR from IIR. External inflammatory RR (EIRR) usually occurs in infected necrotic teeth, and on radiographic examination, roots may have shorter apices than normally expected. In ERR, the root is irregular in appearance [4].

Cone-beam computed tomography (CBCT) definitively diagnoses resorption location, type, and size. It aids in treatment selection and feasibility assessment. Despite relatively diminished patient radiation exposure in CBCT, it remains notably higher than in conventional periapical radiography. Hence, CBCT utilization warrants contemplation when prognosis modification is anticipated [9].

To determine the treatment method, criteria such as the patient's age, tooth position, occlusion, presence and dimensions of root perforations, periodontal tissue condition, and restoration of the relevant tooth should be considered [8]. Depending on the situation, different methods can be used: follow-up of the relevant tooth if the tooth is asymptomatic, non-surgical root canal treatment (RCT), conservative therapy combined with surgical treatment, regenerative endodontics procedures, or relevant tooth extraction [8].

Depending on the presence and size of the perforation, non-surgical RCT or combined treatment can be applied. The main goal of treatment is to remove bacteria and disinfect the root canals, preventing further resorption. The use of calcium hydroxide as an intracanal medicament maximizes the effect of disinfection procedures [8]. If the root perforation occured, bioactive hydraulic silicate cement such as mineral trioxide aggregate (MTA) and biodentine should be used to repair the perforation [10–12]. Due to the irregular nature of the resorption area, using the thermoplastic root canal filling techniques are more effective [4].

Surgery is required if the perforation site is not reachable through standard orthograde approaches. Access to the root canal system is established before surgical repair, followed by maintaining canal patency. Repairing the perforation with bioactive hydraulic silicate cement after debridement is advised. Then, proceed with orthograde RCT [11].

Regenerative endodontics procedures, especially in cases of large perforations, may stop the resorption process and induce the formation of hard tissue, thus improving the long-term prognosis of the affected tooth. However, more clinical studies are needed to investigate the efficacy of regenerative endodontic procedures in the treatment of resorption [4]. Depending on the extent of resorption, the affected tooth may become weak, fractured, or irreparable, necessitating extraction in such cases. [4].

The aim of this study was to present a case report on a tooth exhibiting both external and internal RR, along with sytematic review of similar case reports treated with different treatment protocols.

Materials and Methods

Search Strategies and Study Selection

This literature review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) checklist [13]. The research questions were described according to the PICO question:

"Do different treatment protocols lead to differences in prognosis or clinical outcomes in patients with both external and internal (combined) root resorption (CRR) resulting in perforation?":

- P: "Patients with both external and internal (combined) root resorption (CRR) resulting in perforation"
- I: "Different treatment protocols"
- C: "Comparison group or alternative treatment, if applicable"
- O: "Prognosis or clinical outcomes"

The initial search was made on the PubMed and Web of Science databases. The inclusion criteria were cases

with perforation due to both external and internal resorption, cases with a follow-up period of at least 6 months, and articles published between December 01, 2012 and July 01, 2022. Cases without perforation were excluded. This literature review examined only case reports and case series.

Quality Assessment

Quality assessment was made according to a study by Murad *et al.* [14] "Methodological Quality and Synthesis of Case Series and Case Reports".

Results

Case Report

A 35-year-old female patient applied to the Department of Endodontics, Akdeniz University Faculty of Dentistry, due to discoloration on her maxillary anterior teeth. RCT was applied to tooth #11 eleven years ago and the patient complained about crown restorations. She had no symptoms other than discoloration. From the the patient history, it was determined that the patient had no systemic diseases. Radiographic and clinical examinations showed inadequate RCTs, apical lesions, and irregularities in the root canal of tooth #11. Discoloration and sinus tract were detected in the apical region of tooth #11. Tooth #21 was diagnosed with apical periodontitis due to inadequate RCT. According to radiographic examination, IRR and ERR were confirmed by CBCT scanning. The CBCT images revealed a communication between the root canal and periapical tissues in the apical third of the root canal, with a perforation in the buccal cortex. Probing revealed no periodontal pocketing around the tooth and mobility within physiological limits. Retreatment and aesthetic restorations were planned for teeth #11 and #21 (Fig. 2A).

The risk of complications following endodontic retreatment was fully explained to the patient and a consent form was signed.

After anesthetic injection of articaine with 1:100 000 epinephrine and isolation of teeth #11 and #21 by rubber dam, the access cavities were prepared. Canal filling contents were removed by using ProTaper retreatment files in the order of D1, D2, and D3 (Dentsply Maillefer, Ballaigues-Switzerland). The initial working length was determined by using an electronic apex locator (Apex ID (SybronEndo)). The root canal of tooth #11 was instrumented with K-files up to #20 and frequently irrigated using chlorhexidine and saline. Due to the existing perforation in the buccal cortex, 2.5% NaOCl was not used as irrigation material. The root canal of tooth #21 was instrumented with K-files up to #20 and frequently irrigated using 2.5% NaOCl followed by a final rinse with 5 mL of chlorhexidine and 17% EDTA. Teeth #11 and #21 were prepared using ProTaper files in the order of X1, X2, X3, X4, and X5 (Dentsply Maillefer, Ballaigues-Switzerland). A single visit retreatment was decided for tooth #21. An epoxy resin-based system sealer (Diaproseal, DiaDent) and guttapercha were used for canal filling. The root canal of tooth #11 was dried and calcium hydroxide (Kalsin, Aktu Inc. Izmir, Turkey) was placed as intracanal medicament. Then, teeth were restored with a temporary filling material (conventional glass ionomer cement) (Nova Glass F, Imicryl Dental). The follow-up appointment was scheduled in two weeks.

After two weeks, the surgical site was anesthetized using articaine-epinephrine 1:100,000. The first crevicu-

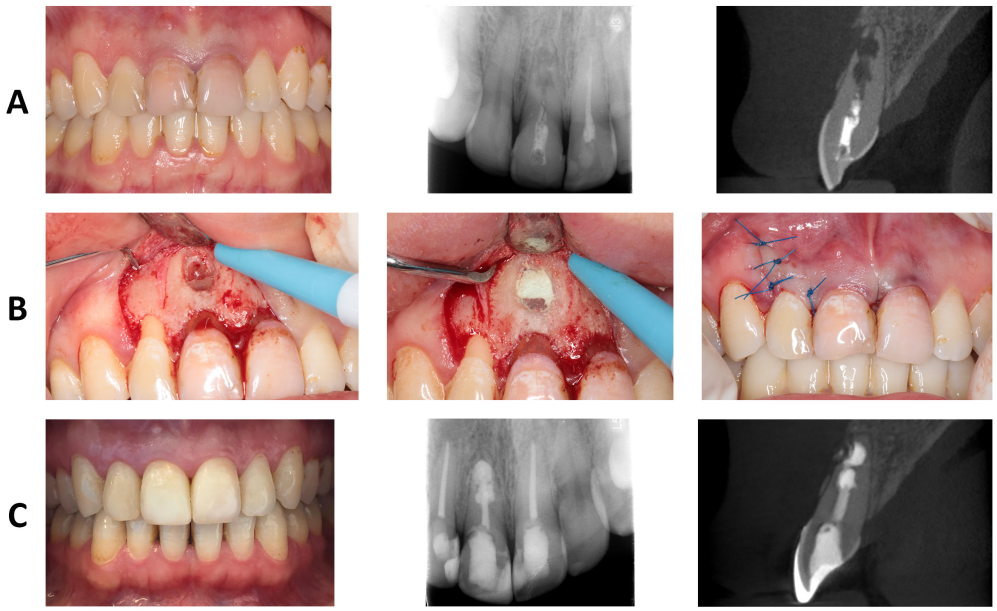

Figure 2. A) Preoperative intraoral image, periapical radiography, and CBCT image of the tooth presented from left to right; B) intraoperative area after flap elevation, sealing of resorption area with MTA, and postoperative intraoral image presented from left to right; C) intraoral image, periapical radiography, and CBCT image of the tooth after one-year follow-up presented from left to right.

lar incision was made and a full-thickness flap was elevated buccally (Fig. 2B). A beveled vertical releasing incision was performed in the buccal gingiva of the tooth #12 inter-dental space, extending just beyond the mucogingival line to provide appropriate mechanical access to the resorption area. Following the reflection, the defect region was thoroughly degranulated and debrided using Gracey curettes #3 and #4. The resorption area in the apical third was covered using MTA (Cerkamed Medical Company, Stalowa, Poland). The flaps were then repositioned with 4-0 non-absorbable, monofilament, and polypropylene suture (Propylene, Doğsan, Trabzon, Turkey). Antibiotics and analgesics were prescribed. In the postoperative period, the patient was prescribed antibiotics (1000 mg amoxicillin + potassium clavulanic acid after checking medical history for potential allergies, twice a day for seven days), anti-inflammatory analgesics (25 mg dexketoprofen, three times a day) and chlorhexidine digluconate rinses (0.12%, twice a day for two weeks). On the 10^{th} day following surgery, stitches were removed. The patient was monitored for a 2-week period to observe the healing process, and a follow-up appointment was scheduled two weeks later.

At the subsequent appointment, the patient reported no history of pain or infection. MTA was used for filling the apical third. Afterward, the coronal part of the root canal was filled with continuous heat (the Calamus dual 3D (Dentsply Maillefer, Ballaigues, Switzerland) Obturation System) using the vertical condensation technique. Postoperative radiography demonstrated complete filling of the apical third of the root canal and homogeneous filling of the root canal. The permanent restoration was done using composite resin (Arabesk, Voco, Cuxhaven, Germany) (Fig. 2C).

After 6 and 12 months of treatment, the patient was scheduled for follow-up visits, during which no problems were encountered.

As a result of the treatment, the patient reported no complaints, especially regarding the discoloration of her teeth, and expressed high satisfaction with the aesthetic outcome.

Identification and Selection of Relevant Studies

All articles from PubMed and Web of Science were compared, resulting in 101 articles reviewed after eliminating duplicates. The titles and abstracts of the articles were carefully assessed, leading to 23 articles allocated for further review.

Two articles excluded were literature reviews with no case representation. Searching parameters and approach used in this literature review are depicted in Fig. 3.

Characteristics of Included Studies

Twenty-one articles, including case reports and case series (Table 1), were assessed in this literature review. A total of 25 cases of ERR and IRR are presented in Table 1 in detail. A combination of surgical and endodontic treatments was administered in 12 cases, and non-surgical endodontic treatment was performed in 13 cases. Among these cases, 22 cases involved root canal perforation and the remaining three cases did not. The perforation area was filled with MTA in 14 cases, biodentine in 4 cases, calcium enriched mixture (CEM) cement in 2 cases, and zinc oxide eugenol sealers in 2 cases. Calcium hydroxide was used as an intracanal medicament in 19 cases and triple antibiotic paste was preferred in one case. No specific information was available in five cases. Among these cases, composite restoration was employed in 15 cases and crown restoration was preferred in 4 cases. No details were given in 6 cases.

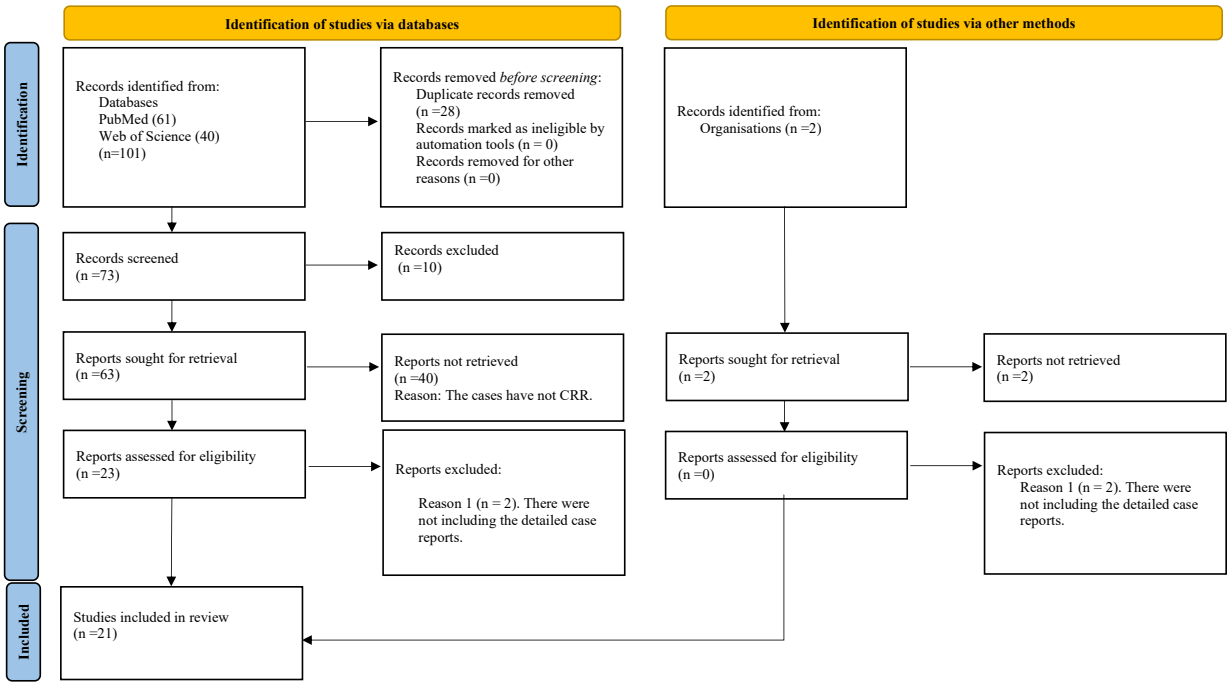

Figure 3. Systematic flow chart of the study selection process.

Table 1. Preoperative and operative factors of the cases in this study.

Author(s)' last name, first initial	Year	Type of article	Number of cases/ Number of teeth	Diagnosis	Type of perforation	Location of perforation	Treatment	Number of visits	Intracanal medication	Obturation material of perforation	Root canal treatment method	Root canal filling paste	Surgical treatment	Type of crown restoration	Follow-up	Prognosis
Abdullah et al. [31]	2017	Case report	2 /1) #11	1) Idiopathic internal root resorption	1) Buccal cortex perforation	1) Middle third of the root	1) Combined non-surgical and surgical treatment	3	1) Calcium hydroxide	1) Mineral trioxide aggregate (MTA)	1) Placing MTA at the apex up to the coronal part of the canal and filling the access cavity with Kalzinol	-	1) Buccal flap	-	1) 3 years	1) succesful
			2) #22	2) Idiopathic internal root resorption	2) -	2) -	2) Non-surgical root canal treatment		2) -	2) MTA	2) Placing MTA in the resorptive cavity up to the orifice of the canal		2) -		2) 3 years	2) succesful
Arifati et al. [29]	2018	Case report	1/#22	External root resorption	Lateral perforation	Middle third of the root	Combined non-surgical and surgical treatment	4	Calcium hydroxide	Calcium silicate-based material (biodentine)	MTA apical plug with a thickness of 5 mm, lateral condensation technique	Without sealer	Full-thickness mucope-riosteal triangular flap	Fiber post, composite restoration	6 months	succesful
Asgary et al. [15]	2014	Case report	1/#12	Inadequate previous root canal treatment and symptomatic apical periodontitis	Buccal cortex perforation	Middle third of the root	Combined non-surgical and surgical treatment	3	-	Calcium-enriched mixture (CEM) cement (BioniqueDent, Tehran, Iran)	Filling the root canal as well as the perforated resorptive root defect with CEM cement (BioniqueDent, Tehran, Iran)	-	Full-thickness flap	-	2 years	succesful
Bendyk-Szeffer et al. [32]	2015	Case report	1/#16	Perforating internal root resorption with chronic apical periodontitis accompanied by sinusitis of odontogenic origin	Palatal cortex	Apical third of the root	Non-surgical root canal treatment	3	Calcium hydroxide	MTA	Obturation of the root canal with thermoplasticized gutta-percha and sealer	AH Plus sealer (Dentsply DeTrey, Konstanz, Germany)	-	Composite restoration	1 year	succesful
Carnio et al. [16]	2015	Case report	1/#15	External root resorption	Buccal cortex perforation	Middle third of the root	Combined non-surgical and surgical treatment	-	-	MTA	-	-	Coronally advanced flap (CAF)	Composite restoration	30 months	succesful
Pereira da Costa et al. [33]	2020	Case report	1/#11	Necrotic pulp with asymptomatic apical periodontitis with perforating internal root resorption	Lateral perforation	Middle third of the root	Non-surgical root canal treatment	2	-	MTA	Obturation of the canal upper to the resorptive lesion with MTA	-	-	Composite restoration	5 years and 9 months	succesful
Deep et al. [17]	2021	Case report	1/#11	Inflammatory internal root resorption	Labial cortex perforation	Coronal third of the root	Combined non-surgical and surgical treatment	2	-	MTA	Placing an 80-no. gutta-percha cone placed the canal, with freshly mixed white MTA Angelus placed over it	-	Full-thickness flap	Resin-modified glass ionomer and composite restoration	1 year	succesful
Es-naashari et al. [34]	2015	Case report	1/#21	Inflammatory internal root resorption with pulp necrosis	Labial cortex perforation	Middle third of the root	Non-surgical root canal treatment	2	Calcium hydroxide with saline	CEM cement	Filling the whole canal space with CEM cement (BioniqueDent, Tehran, Iran)	CEM cement	-	Permanent crown restoration	1 year	succesful
Gayathri et al. [18]	2014	Case report	1/#21	Inflammatory internal resorption	Buccal cortex perforation	Middle third of the root	Combined non-surgical and surgical treatment	3	Calcium hydroxide	MTA	Lateral and sectional condensation methods	-	Full-thickness flap	Composite restoration	10 months	succesful
Ghafoor et al. [30]	2017	Case report	1/#21	Chronic asymptomatic periapical periodontitis with external inflammatory root resorption	Facial and proximal perforation	Apical third of the root	Non-surgical root canal treatment	2	Metapex MetaBiomed	Zinc oxide eugenol (Caulk Dentsply IRM)	Obtura Sybron Endo	-	Papilla preservation flap	Composite restoration	6 months	succesful
Li et al. [19]	2016	Case series	2/1) #45	1) Perforating internal root resorption	1) -	1) Middle third of the root	1) Non-surgical root canal treatment	1)3	1) Calcium hydroxide	1) MTA	1) Lateral compaction	1) Sealapex: SybronEndo	1) -	1) Composite restoration	1) 19 months	1) succesful
			2) #21	2) Apical abscess with perforating internal root resorption	2) Labial cortex perforation	2) Middle third of the root	2) Combined non-surgical and surgical treatment	2)more then 2 visits	2) Calcium hydroxide	2) MTA	2) Lateral compaction	2) Grossman's sealer	2) Triangular flap	2) -	2) 28 months	2) succesful

Table 1 (Continued).

Author(s)' last name, first initial	Year	Type of article	Number of cases/ Number of teeth	Diagnosis	Type of perforation	Location of perforation	Treatment	Number of visits	Intracanal medication	Obturation material of perforation	Root canal treatment method	Root canal filling paste	Surgical treatment	Type of crown restoration	Follow-up	Prognosis
Mehra et al. [20]	2018	Case series	3/1) #21	1) Inflammatory non-perforating internal root resorption with symptomatic apical periodontitis	1) -	1) Middle and apical thirds of the root	1) Non-surgical root canal treatment	1) 2	1) Calcium hydroxide	1) MTA	1) Backfilling with thermoplasticized gutta-percha	1) AH Plus (Dentsply Maillefer, USA)	1) -	1) Permanent crown restoration	1) 18 months	1) succesful
			2) #21	2) Inflammatory perforating internal root resorption	2) Lateral perforation	2) Coronal third of the root	2) Combined non-surgical and surgical treatment	2) 3	2) Calcium hydroxide	2) MTA	2) Backfilling with thermoplasticized gutta-percha till the middle third of the canal. Seling the remaining canal with Ribbond fibres (Ribbond, USA)	2) -	2) Full-thickness flap	2) Composite restoration	2) 18 months	2) succesful
			3) #23	3) Invasive cervical root resorption	3) Buccal and palatal perforation	3) Coronal third of the root	3) Combined non-surgical and surgical treatment	3) 2	3) Calcium hydroxide	3) Biodentine	3) Backfilling with thermoplasticized gutta-percha	3) MTA Fillapex (Angelus, Brazil)	3) Full-thickness flap	3) Composite restoration	3) 4 years	3) succesful
Moham-madi et al. [21]	2012	Case report	1/#11	Inflammatory perforating internal root resorption	Lateral perforation	Middle third of the root	Non-surgical root canal treatment	3	Calcium hydroxide	MTA	Lateral compaction technique	AH26 (Dentsply, Konstanz, Germany) sealer	-	Post-core and crown restoration	18 months	succesful
Nunes et al. [22]	2012	Case report	1/#12	Perforating internal root resorption	Lateral perforation	Middle third of the root	Non-surgical root canal treatment	6	Calcium hydroxide with saline	Pulp canal sealer (Kerr Sybron Dental Specialties, Glendora, CA, USA)	System B (SybronEndo Corporation, Orange, CA, USA) with a Buchanam FM (fine medium) plugger	Pulp canal sealer (Kerr Sybron Dental Specialties, Glendora, CA, USA)	-	Light-cured resin.	11 years and 8 months	succesful
Olivieri et al. [26]	2012	Case report	1/#21	Pulp necrosis with chronic periradicular periodontitis associated with inflammatory external root resorption	Palatal perforation	Apical third of the root	Non-surgical root canal treatment	5	Calcium hydroxide	white MTA	System B .06 plugger (Sybron Endo)	Resin cement (Topseal, Dentsply Maillefer)	-	Composite restoration	17 months	unsuccesful
Pawar et al. [27]	2022	Case report	1/#23	Internal root resportion	Lateral perforation	Middle third of the root	Combined non-surgical and surgical treatment	4	Calcium hydroxide	Biodentine (Septodont Saint Maur-des Fosses, France)	A down pack of gutta percha to obturate the resorption cavity using an E & Q pen	AH Plus sealer (Dentsply, Konstanz, Germany)	Full-thickness mucope-riosteal flap	All-ceramic crown	12 months	succesful
Sierra-Lorenzo et al. [23]	2013	Case report	1/#21	Irreversible pulpitis with perforating internal root resorption	Lateral perforation	Middle third of the root	Combined non-surgical and surgical treatment	3	Calcium hydroxide	MTA	A down pack motion using System B	Sealer cement (Topsealer)	Full-thickness mucope-riosteal flap	Composite restoration	5 years	succesful
Sayyad Soufdoost et al. [28]	2020	Case report	1/#11	External root resorption	Lateral perforation	Apical third of the root	Conventional root canal therapy with biodentine	2	Calcium hydroxide	Biodentine (Septodont)	Thermoplasticized gutta-percha (Obtura III Max, Kerr)	-	-	Composite restoration (3M ESPE)	12 months	succesful
Subay et al. [24]	2018	Case report	1/#11	Internal replacement resorption	Lateral perforation	Middle third of the root	Non-surgical root canal treatment	7	Calcium hydroxide with saline	white MTA	Vertical condensation	-	-	Composite restoration (Supreme, 3M ESPE, Dental Products, MN, USA)	6 years	succesful
Utneja et al. [25]	2012	Case report	1/#21	External root resorption	Lateral perforation	Middle third of the root	Non-surgical root canal treatment	3	Triple antibiotic paste (ciprofloxacin, metronidazole, and minocycline)	MTA	MTA	MTA	-	-	18 months	succesful
Yildirim et al. [35]	2019	Case report	1/#11	Internal root resorption	Buccal perforation	Middle and apical thirds of the root	Combined non-surgical and surgical treatment	7	Calcium hydroxide	white MTA	White MTA	white MTA	Full-thickness mucope-riosteal flap	-	3 years	succesful

A total of 25 teeth were treated in these 21 articles. Specifically, 16 of the treated teeth were maxillary centrals, four were maxillary laterals, one was a maxillary canine, one was a maxillary premolar, one was a mandibular premolar, and one was a maxillary molar. In our case report, maxillary central teeth were also treated. In the examined cases, 24 out of 25 teeth displayed successful outcomes, with one tooth requiring extraction due to orthodontic considerations.

Risk of Bias Assessment

The detailed presentation of the included studies can be found in Table 2. In all 21 of the included articles, the case selection criteria were not specified, resulting in their categorization as "unclear" in all articles. Diagnostic methods were not fully elaborated in 11 of the articles [15–25], and diagnosis was not specified in 3 of them [26–28]. Moreover, in 3 of the included articles [18, 29, 30], the follow-up period was less than one year. However, all articles clearly stated the treatment methods, suggesting their potential applicability in clinical practice.

Discussion

IRR is regarded as rare but its frequency is not well known [36]. Most of the articles on IRR in the literature are case reports involving resorption treatment [22, 24].

In both physiological and pathological conditions, bone and RR involve an interaction between odontoblasts-odontoclasts and osteoblasts-osteoclasts, which is regulated by the OPG/RANK/RANKL signaling pathway expressed by periodontal ligament (PDL) cells [7]. Some studies [37, 38] have reported that cementum and dental pulp can express RANKL as well. For bone homeostasis and bone remodeling, the RANK/RANKL/OPG signaling pathway is of great importance. RANKL secreted by osteoblasts and osteocytes, which are stimulated by transcription factors, induces the differentiation of macrophages into osteoclasts. This results in osteoclastogenesis and osteolysis of the bone. OPG secreted by osteoblasts acts as a semi-ligand for RANK and antagonizes the action of RANKL resulting in the inhibition of bone resorption.

Patel *et al.* [39] concluded in an *in vivo* study that despite periapical radiography is an acceptable diagnostic tool, CBCT is more accurate in diagnosing internal resorption; consequently, this method may increase the chance of correct treatment and prognosis. Although analog and digital periapical radiographs taken in the diagnosis of RR provide good results, they have disadvantages because the 3D anatomy of the radiographed area is projected as a 2D image. In our case, we used CBCT for a definitive diagnosis as well.

Factors such as the patient's age, perforation presence, and final restorative treatment should be considered when deciding on the treatment method [8]. According to Nilsson *et al.* [8], RR can be treated by orthograde RCT, retrograde apical treatment, or extraction.

There is no consensus regarding the most effective technique for removing old gutta-percha and preparing roots for new retreatments in endodontics. An *in vitro* study by Khalilak *et al.* [40] evaluated the efficacy of H-file and ProTaper with or without chloroform in the removal of gutta-percha during retreatment. The study found that ProTaper retreatment files with chloroform were faster and more effective in removing gutta-percha in straight root canals compared to hand files. A study by Rodig *et al.* [41] compared the efficacy of two rotary NiTi retreatment systems and hand files in removing gutta-percha. As a result of their studies, although rotary NiTi systems removed significantly more dentin than hand files, retreatment with rotary NiTi systems resulted in high procedural errors. Considering the results of these studies, we performed our treatment using ProTaper retreatment files.

Calcium hydroxide is one of the most commonly used intracanal medicaments. For multi-visit management, Ledermix and antibiotic pastes are comparable to calcium hydroxide, but attention should be paid to potential tooth discoloration [42]. Ledermix is a paste containing 1% triamcinolone and 3% demeclocycline, used as an intracanal medicament. In our case, we used calcium hydroxide, which has various advantages such as its antibacterial effects, ease of use, and biocompatibility. The manufacturer (Henry Schein UK Holdings Limited 2013) warns of possible allergic reactions to Ledermix paste, but over a long period, systemic side effects are extremely rare. However, several allergic reactions such as rash, anaphylaxis, urticaria, and pruritis may develop [43]. Tooth discoloration is one of the biggest disadvantages of triple antibiotic pastes. A study by Malu *et al.* [44] has shown that triple antibiotic paste is the paste causing the most discoloration when compared to Ledermix and other antibiotic pastes. As a result, in some cases, the use of a double antibiotic paste containing only ciprofloxacin and metronidazole has been recommended. In addition, the use of a double antibiotic paste or a triple antibiotic paste for one month has been found to significantly reduce dentin microhardness [44].

According to Nilsson *et al.* [8], orthograde RCT is the preferred method in RR treatments as it removes granulation tissue and infected tissues. In addition, they recommended a combination of surgical and conventional RCT with MTA or calcium silicate cement as another option in cases where canal lesion cannot be managed. Altundasar *et al.* [45] treated a case of perforating IRR using a combination of MTA and periodontal surgery. In the treatment of perforating resorptions, the surgical approach can be used to prevent extrusion of the filling used due to perforation during RCT. Therefore, we applied combined surgery and RCT in our treatment.

A perfect material to repair the perforation area should be biocompatible and demonstrate good sealing ability [46]. Common materials that have been investigated in clinical studies are amalgam, zinc oxide/calcium sulfate cement, glass-ionomer cement, composite, zinc oxide/eugenol cement (IRM, SuperEBA), and calcium silicate types of cement (MTA), biodentine and bioceramic root repair material [47]. MTA and biodentine have good biocompatibility and adequate sealing property. Arifati *et al.* [29] used biodentine as a filling due to its handling properties and fast

Table 2. Quality/bias assessment [14].

	Selection 1. Does the patient(s) represent(s) the whole experience of the investigator (centre) or is the selection method unclear to the extent that other patients with similar presentation may not have been reported?	Ascertainment 2. Was the exposure adequately ascertained?	Ascertainment 3. Was the outcome adequately ascertained?	Causality 4. Were other alternative causes that may explain the observation ruled out?	Causality 5. Was there a challenge/rechallenge phenomenon?	Causality 6. Was there a dose–response effect?	Causality 7. Was follow-up long enough for outcomes to occur?	Reporting 8. Is the case(s) described with sufficient details to allow other investigators to replicate the research or to allow practitioners make inferences related to their own practice?
Abdullah et al. [31] (2017)	unclear	yes	yes	yes	yes	no	yes	yes
Arifati et al. [29] (2018)	unclear	yes	yes	yes	no	no	no	yes
Asgary et al [15] (2014)	unclear	no	yes	yes	no	no	yes	yes
Bendyk-Szeffer et al. [32] (2015)	unclear	yes	yes	yes	no	no	yes	yes
Carnio et al. [16] (2015)	unclear	no	yes	yes	unclear	no	yes	yes
Pereira da Costa et al. [33] (2020)	unclear	yes	yes	yes	no	no	yes	yes
Deep et al. [17] (2021)	unclear	no	yes	yes	yes	no	yes	yes
Esnaashari et al. [34] (2015)	unclear	yes	yes	yes	yes	no	yes	yes
Gayathri et al. [18] (2014)	unclear	no	yes	yes	yes	no	no	yes
Ghafoor et al. [30] (2017)	unclear	yes	yes	yes	no	no	no	yes
Li et al. [19] (2016)	unclear	no	yes	yes	yes	no	yes	yes
Mehra et al. [20] (2018)	unclear	no	yes	no	yes	no	yes	yes
Mohammadi et al. [21] (2012)	unclear	no	yes	no	no	no	yes	yes
Nunes et al. [22] (2012)	unclear	no	yes	no	yes	no	yes	yes
Olivieri et al. [26] (2012)	unclear	yes	no	yes	yes	no	yes	yes
Pawar et al. [27] (2022)	unclear	yes	no	yes	no	no	yes	yes
Sierra-Lorenzo et al. [23] (2013)	unclear	no	yes	yes	yes	no	yes	yes
Sayyad Soufdoost et al. [28] (2020)	unclear	yes	no	yes	yes	no	yes	yes
Subay et al. [24] (2018)	unclear	no	yes	yes	yes	no	yes	yes
Utneja et al. [25] (2012)	unclear	no	yes	yes	yes	no	yes	yes
Yildirim et al. [35] (2019)	unclear	yes	yes	yes	yes	no	yes	yes

setting time. MTA has many advantages such as biocompatibility, good sealing ability, and physical durability [48]. Based on these properties, MTA was used to seal the root perforation. On the other hand, biodentine was used as a sealing material in various case reports and successful results were obtained [20, 27, 28]. CEM cement which consists of different calcium compounds (i.e., calcium oxide, calcium phosphate, calcium carbonate, calcium silicate, calcium sulfate, calcium hydroxide, and calcium chloride) can be used as a perforation filling as well [49].

Restoration of root canal-treated teeth can be difficult due to the alternation between vital and non-vital teeth. One of the most important factors affecting the choice of post-treatment restoration is the amount of tooth remaining. Direct restorations using restorative materials or indirect restorations such as cast metal or ceramic (porcelain) crowns may be considered treatment options. The durability and cost of the restoration are effective in the selection of restoration as well [50]. In our case, we preferred aesthetic composite restorations as permanent restoration after RCT, as the loss of substance in the teeth was low.

Conclusions

In the present case report, a patient who had both ERR and IRR was treated with MTA and flap operation, with no subsequent complications during the follow-up sessions. In this systematic review, we assessed the prognosis and clinical outcomes of different treatment protocols appied to patients with both ERR and IRR resulting in perforation. Among the 21 reports included in our analysis, 24 out of 25 treated teeth demonstrated successful outcomes, while only one tooth necessitated extraction. This suggests that various treatment approaches can lead to favorable outcomes in these complex cases. Moreover, accurate and early diagnosis, often aided by CBCT, is essential in determining

the outcome of teeth affected by both ERR and IRR.

Ethical Statement

This case report was conducted in accordance with the principles outlined in the Helsinki Declaration and adhered to ethical guidelines.

Informed Consent

Written and verbal informed patient consent was obtained for this case report.

Data Availability

This report presents the clinical details and management of an individual clinical episode; data sharing not applicable.

Conflict of Interest

The authors declared no conflict of interest.

Financial Disclosure

Authors declare that they have no funding.

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