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

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 preccementum 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...
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 IRR. 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 occurred, 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 systematic 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 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 gutta-percha 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, Doğan, 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 10th 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) Obtura 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.
<table>
<thead>
<tr>
<th>Author(s)' last name, first initial</th>
<th>Year</th>
<th>Type of article</th>
<th>Number of cases/ Number of teeth</th>
<th>Diagnosis</th>
<th>Type of perforation</th>
<th>Location of perforation</th>
<th>Treatment</th>
<th>Number of visits</th>
<th>Intracanal medication</th>
<th>Root canal treatment method</th>
<th>Root canal filling paste</th>
<th>Surgical treatment</th>
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<th>Follow-up</th>
<th>Prognosis</th>
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<td>Abdullah et al. [31]</td>
<td>2017</td>
<td>Case report</td>
<td>2/1 #11</td>
<td>1) Idiopathic internal root resorption</td>
<td>1) Buccal cortex perforation</td>
<td>1) Middle third of the root</td>
<td>1) Combined non-surgical and surgical treatment</td>
<td>3</td>
<td>1) Calcium hydroxide</td>
<td>1) Placing MTA at the apex up to the coronal part of the canal and filling the access cavity with Kalgan</td>
<td>1) Buccal flap</td>
<td>-</td>
<td>1) successful</td>
<td>3 years</td>
<td>1) successful</td>
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<td>Afifi et al. [29]</td>
<td>2018</td>
<td>Case report</td>
<td>1/#22</td>
<td>2) Idiopathic internal root resorption</td>
<td>2) Middle third of the root</td>
<td>2) Combined non-surgical and surgical treatment</td>
<td>4</td>
<td>Calcium hydroxide</td>
<td>2) MTA</td>
<td>MTA apical plug with a thickness of 5 mm, lateral condensation technique</td>
<td>Without sealer</td>
<td>Full-thickness mucoperiosteal triangular flap</td>
<td>Fiber post, composite restoration</td>
<td>6 months</td>
<td>successful</td>
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<td>Asgary et al. [15]</td>
<td>2014</td>
<td>Case report</td>
<td>1/#12</td>
<td>Inadequate previous root canal treatment and symptomatic apical periodontitis</td>
<td>Buccal cortex perforation</td>
<td>Middle third of the root</td>
<td>Combined non-surgical and surgical treatment</td>
<td>3</td>
<td>-</td>
<td>Filling the root canal as well as the perforated resorptive root defect with CEM cement</td>
<td>Full-thickness flap</td>
<td>-</td>
<td>2 years</td>
<td>successful</td>
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<td>2015</td>
<td>Case report</td>
<td>1/#16</td>
<td>Perforating internal root resorption with chronic apical periodontitis accompanied by sinusitis of odontogenic origin</td>
<td>Palatal cortex</td>
<td>Apical third of the root</td>
<td>Non-surgical root canal treatment</td>
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<td>Calcium hydroxide</td>
<td>MTA</td>
<td>Obturation of the root canal with thermoplasticized gutta-percha and sealer</td>
<td>AH Plus sealer (Dentsply DeTrey, Konstanz, Germany)</td>
<td>-</td>
<td>Composite restoration</td>
<td>1 year</td>
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<td>2015</td>
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<td>1/#15</td>
<td>External root root resorption</td>
<td>Buccal cortex perforation</td>
<td>Middle third of the root</td>
<td>Combined non-surgical and surgical treatment</td>
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<td>-</td>
<td>MTA</td>
<td>Coronally advanced flap (CAF)</td>
<td>Composite restoration</td>
<td>30 months</td>
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<td>2020</td>
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<td>1/#11</td>
<td>Necrotic pulp with asymptomatic apical periodontitis with perforating internal root resorption</td>
<td>Lateral cortex</td>
<td>Middle third of the root</td>
<td>Non-surgical root canal treatment</td>
<td>2</td>
<td>-</td>
<td>MTA</td>
<td>Obturation of the canal upper to the resorptive lesion with MTA</td>
<td>-</td>
<td>Composite restoration</td>
<td>5 years and 9 months</td>
<td>successful</td>
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<td>Deep et al. [17]</td>
<td>2021</td>
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<td>1/#11</td>
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<td>Labial cortex perforation</td>
<td>Coronal third of the root</td>
<td>Combined non-surgical and surgical treatment</td>
<td>2</td>
<td>-</td>
<td>MTA</td>
<td>Placing an 80-no. gutta-percha cone placed the canal, with freshly mixed white MTA Angelus placed over it</td>
<td>Full-thickness flap</td>
<td>Resin-modified glass ionomer and composite restoration</td>
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<td>1/#21</td>
<td>Inflammatory internal root resorption with pulp necrosis</td>
<td>Labial cortex perforation</td>
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<td>Non-surgical root canal treatment</td>
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<td>Calcium hydroxide with CEM cement saline</td>
<td>-</td>
<td>Filling the whole canal space with CEM cement (BioniqueDent, Tehran, Iran)</td>
<td>CEM cement</td>
<td>Permanen crown restoration</td>
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<td>Buccal cortex perforation</td>
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<td>MTA</td>
<td>Lateral and sectional condensation methods</td>
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<td>1/#21</td>
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<td>Facial and proximal perforation</td>
<td>Apical third of the root</td>
<td>Non-surgical root canal treatment</td>
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<td>Metapex MetaBiomed</td>
<td>Zinc oxide eugenol (Caulk Dentsply IRM)</td>
<td>Obtura Sybron Endo</td>
<td>-</td>
<td>Papilla preservation flap</td>
<td>Composite restoration</td>
<td>6 months</td>
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<td>1) Middle third of the root</td>
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<td>1) MTA</td>
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<td>1) Sealapex: SybronEndo</td>
<td>1) Composite restoration</td>
<td>19 months</td>
<td>1) successful</td>
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<td>2) Apical abscess with perforating internal root resorption</td>
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<td>2) Combined non-surgical and surgical treatment</td>
<td>2) More than 2 visits</td>
<td>2) Calcium hydroxide</td>
<td>2) MTA</td>
<td>2) Lateral compaction</td>
<td>2) Grossman’s sealer</td>
<td>2) Triangular flap</td>
<td>28 months</td>
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<td>Root canal filling paste</td>
<td>Surgical treatment</td>
<td>Type of crown restoration</td>
<td>Follow-up</td>
<td>Prognosis</td>
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<td>1) Non-surgical root canal treatment</td>
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<td>1) Calcium hydroxide</td>
<td>1) Backfilling with thermoplasticized gutta-percha</td>
<td>1) AH Plus (Dentsply Maillefer, USA)</td>
<td>1) -</td>
<td>1) Permanent crown restoration</td>
<td>1) 18 months</td>
<td>1) successful</td>
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<td>2/2</td>
<td>2) Inflammatory perforating internal root resorption</td>
<td>2) Lateral perforation</td>
<td>2) Calcium hydroxide</td>
<td>2) MTA</td>
<td>2) Full-thickness flap</td>
<td>2) Composite restoration</td>
<td>2) 18 months</td>
<td>2) successful</td>
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<td>3/2</td>
<td>3) Invasive cervical root resorption</td>
<td>3) Buccal and palatal perforation</td>
<td>3) Calcium hydroxide</td>
<td>3) Biodentine</td>
<td>3) Full-thickness flap</td>
<td>3) Composite restoration</td>
<td>3) 4 years</td>
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<td>MTA</td>
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<td>Post-core and crown restoration</td>
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<td>Perforating internal root resorption</td>
<td>Lateral perforation</td>
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<td>Calcium hydroxide with saline</td>
<td>System B (SybronEndo Corporation, Orange, CA, USA) with a Buchanam FM (fine medium) plugger</td>
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<td>-</td>
<td>Light-cured resin</td>
<td>11 years and 8 months</td>
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<td>Case report</td>
<td>1/21</td>
<td>Pulp necrosis with chronic periradicular periodontitis associated with inflammatory external root resorption</td>
<td>Palatal perforation</td>
<td>Apical third of the root</td>
<td>Calcium hydroxide</td>
<td>white MTA</td>
<td>System B .06 plugger (SybronEndo)</td>
<td>-</td>
<td>-</td>
<td>Composite restoration</td>
<td>17 months</td>
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<td>1/23</td>
<td>Internal root resorption</td>
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<td>Middle third of the root</td>
<td>Combined non-surgical and surgical treatment</td>
<td>Calcium hydroxide</td>
<td>Biodentine (Septodont Saint Maur-des Fosses, France)</td>
<td>A down pack of gutta percha to obturate the resorption cavity using an E &amp; Q pen</td>
<td>AH Plus sealer (Dentsply, Konstanz, Germany)</td>
<td>Full-thickness mucoperiosteal flap</td>
<td>All-ceramic crown</td>
<td>12 months</td>
<td>successful</td>
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<td>Sierra-Lorenzo et al. [23] 2013</td>
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<td>1/21</td>
<td>Irreversible pulpitis with perforating internal root resorption</td>
<td>Lateral perforation</td>
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<td>Combined non-surgical and surgical treatment</td>
<td>Calcium hydroxide</td>
<td>MTA</td>
<td>A down pack motion using System B</td>
<td>Sealer cement (Topsealer)</td>
<td>Full-thickness mucoperiosteal flap</td>
<td>Composite restoration</td>
<td>5 years</td>
<td>successful</td>
<td></td>
</tr>
<tr>
<td>Sayyad Soufdoost et al. [28] 2020</td>
<td>Case report</td>
<td>1/11</td>
<td>External root resorption</td>
<td>Lateral perforation</td>
<td>Apical third of the root</td>
<td>Conventional root canal therapy with biocemente</td>
<td>Calcium hydroxide</td>
<td>Biodentine (Septodont)</td>
<td>Thermoplasticized gutta-percha (Obtura III Max, Kerr)</td>
<td>-</td>
<td>-</td>
<td>Composite restoration (3M ESPE)</td>
<td>12 months</td>
<td>successful</td>
<td></td>
</tr>
<tr>
<td>Subay et al. [24] 2018</td>
<td>Case report</td>
<td>1/11</td>
<td>Internal replacement resorption</td>
<td>Lateral perforation</td>
<td>Middle third of the root</td>
<td>Non-surgical root canal treatment</td>
<td>Calcium hydroxide with white MTA saline</td>
<td>Vertical condensation</td>
<td>-</td>
<td>-</td>
<td>Composite restoration (Supreme, 3M ESPE, Dental Products, MN, USA)</td>
<td>6 years</td>
<td>successful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Utnaja et al. [25] 2012</td>
<td>Case report</td>
<td>1/21</td>
<td>External root resorption</td>
<td>Lateral perforation</td>
<td>Middle third of the root</td>
<td>Non-surgical root canal treatment</td>
<td>Triple antibiotic paste (ciprofloxacin, metronidazole, and minocycline)</td>
<td>MTA</td>
<td>MTA</td>
<td>MTA</td>
<td>18 months</td>
<td>successful</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yildirim et al. [35] 2019</td>
<td>Case report</td>
<td>1/11</td>
<td>Internal root resorption</td>
<td>Buccal perforation</td>
<td>Middle and apical thirds of the root</td>
<td>Combined non-surgical and surgical treatment</td>
<td>Calcium hydroxide</td>
<td>white MTA</td>
<td>White MTA</td>
<td>white MTA</td>
<td>Full-thickness mucoperiosteal flap</td>
<td>-</td>
<td>3 years</td>
<td>successful</td>
<td></td>
</tr>
</tbody>
</table>
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% trimacinolone 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/ephengol 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].

<table>
<thead>
<tr>
<th>Study</th>
<th>Selection 1</th>
<th>Ascertainment 1</th>
<th>Ascertainment 2</th>
<th>Ascertainment 3</th>
<th>Causality 4</th>
<th>Causality 5</th>
<th>Causality 6</th>
<th>Causality 7</th>
<th>Reporting 8</th>
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<td>yes</td>
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<td>yes</td>
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<tr>
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<td>Pereira da Costa et al. [33] (2020)</td>
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<tr>
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<tr>
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</tbody>
</table>

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 applied 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.

**References**


