Complications Caused by Apical Extrusion of Sodium Hypochlorite. A Case Report Study and Systematic Review

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AIM: Sodium hypochlorite (NaOCl) is widely used as an irrigant during root canal treatments due to its potent antimicrobial properties. However, its inadvertent apical extrusion can lead to significant complications. This study aims to assess the safety and efficacy of NaOCl as an irrigant in endodontic procedures and analyze the risks associated with its apical extrusion.
METHODS: A systematic review and case report study were conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. A literature search was performed in the Web of Science, Scopus, and PubMed databases, limited to articles published in English between 2004 and 2024.
RESULTS: The initial search identified 724 articles, with 267 remaining after the removal of duplicates. Following the application of inclusion criteria, 9 studies were selected for final analysis.
CONCLUSIONS: While NaOCl remains the gold standard for root canal irrigation, improper handling can result in severe complications, including chemical burns and tissue necrosis. The study highlights the importance of implementing safety measures such as accurate irrigation techniques, the use of rubber dams, and side-exit needles to minimize risks. Further research is necessary to refine irrigation protocols and enhance patient safety, emphasizing the need for collaboration among dental professionals for optimal treatment outcomes.

Keywords: apical extrusion; endodontics; irrigant; sodium hypochlorite; NaOCl; sodium hypochlorite extrusion; accident

Introduction

Root canal irrigation represents a fundamental component of endodontic therapy, aiming to thoroughly cleanse and shape the root canal system [1–3]. Its primary objective is to eliminate tissue remnants, bacteria, and toxins from within the canal, thereby ensuring effective disinfection and optimal preparation for obturation [4]. Although mechanical instrumentation is crucial for shaping the canal, it alone is insufficient to fully debride the intricate anatomy of the root canal system [5,6]. The use of irrigating solutions is critical in complementing mechanical preparation. Irrigating solutions play several key roles in root canal treatment (RCT) [7–10]. Effective irrigation solutions must also be biocompatible and non-irritating to surrounding tissues to ensure patient safety and comfort [11–16]. Common irrigants used in endodontics include hydrogen peroxide (H_2O_2), physiological saline, water, sodium hypochlorite (NaOCl), and chlorhexidine (CHX). Among these, NaOCl stands out for its historical and widespread use in endodontic therapy [17–19]. First recommended as an antiseptic by Henry Dakin in 1915, NaOCl has become a staple in root canal procedures due to its potent antimicrobial properties and ability to dissolve both necrotic and vital pulp tissues [20–22]. NaOCl is the most recommended due to its antimicrobial effects and ability to dissolve pulp tissue, but it must be used cautiously, as high concentrations can cause severe health issues if extruded into surrounding tissues [23–25]. Iodine is effective against a wide range of microorganisms, is hypoallergenic, and has low toxicity, though its efficacy can be limited by the collagen matrix in dentin [26]. CHX, another widely used irrigant, exerts its antimicrobial effect by disrupting cell membranes and is effective against a broad spectrum of microorganisms, acting as a bacteriostatic agent at low concentrations and becoming bactericidal at higher concentrations [27–29]. Ethylenediaminetetraacetic acid (EDTA) is a chelating agent used in dentistry to inhibit bacterial growth by depriving bacteria of essential ions [30–32]. It removes calcium from dentin at concentrations of 15–17% and eliminates the smear layer with-

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Table 1. Database search indicators.

Database	Scopus, Web of Science and PubMed
Keywords	A "APICAL EXTRUSION"; B "ENDODONTICS"; C "IRRIGANT"; D "SODIUM HYPOCHORITE"; E "ACCIDENT"
Boolean variable	"AND" and "OR"
Period	2004–2024
Language	English

out harming tissues, but it should be applied for only 1–5 minutes to avoid excessive dentin erosion [33–35]. H_2O_2, another irrigant, generates radicals that attack microbes but is less effective than other agents like NaOCl, and carries risks such as subcutaneous emphysema [36–38]. Irrigation is crucial in endodontic treatment for removing debris, dissolving tissue, and preventing reinfection [39,40]. However, NaOCl can cause complications if extruded beyond the apical foramen, emphasizing the need for careful irrigation (Fig. 1) [41,42].

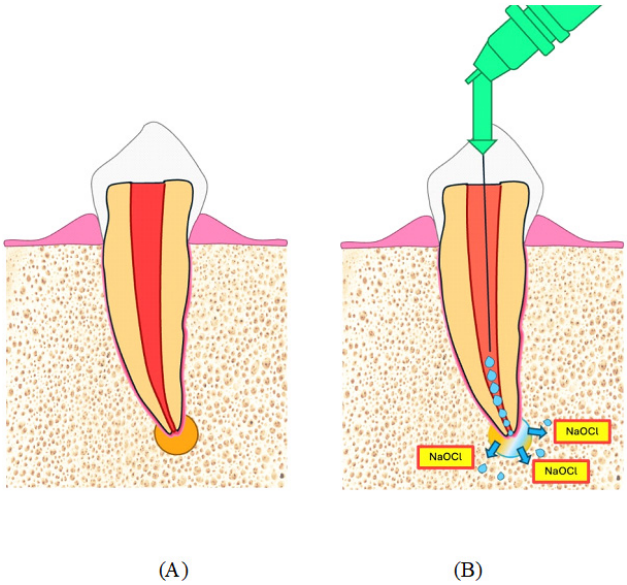

Fig. 1. A possible complication of using sodium hypochlorite (NaOCl) as a root canal irrigant: extrusion through the apical foramen of the treated tooth. The subfigures illustrate (A) an example of apical extrusion and (B) a representative image of periapical pathology, possibly a cyst. Fig. 1 was created by the author using the Microsoft PowerPoint for Microsoft 365 (Version 2408, Microsoft Corporation, Redmond, WA, USA).

Direct contact with periapical tissues can cause significant damage due to their strong proteolytic activity. The irrigation protocol during RCT involves several steps to ensure effective cleaning and disinfection [43–45]. Root canal irrigation should be conducted under rubber dam conditions and with the aid of a microscope [46]. Rubber dams isolate the working area from the oral cavity, preventing contamination, improving efficacy, and avoiding complications such as irritation of the oral mucosa and accidental ingestion of irrigants [47–49]. The selection of irrigation needles is a critical factor in the prevention of hypochlorite accidents during RCT. Various needle designs and sizes, including 23G and 30G side-vented needles as well as 22G and 30G apical-exit needles, have been systematically investigated for their efficacy in debris removal following the initial stages of canal instrumentation [50]. The 30G and side-exit needles are found to best remove debris present in the canal, making them suitable for intracanal cleansing (Fig. 2a,b and Fig. 3) [51].

Irrigation should be performed before starting instrumentation and maintained throughout treatment until closing the canals [52–56].

Continuous research is needed to refine irrigation protocols and develop new, biocompatible solutions, such as electronically activated water, and to improve delivery systems to prevent issues like apical extrusion [57]. Understanding and applying the most effective irrigation techniques can enhance patient safety and ensure successful endodontic outcomes [58–60]. This study aims to evaluate the efficacy and safety of various root canal irrigants, with a particular focus on NaOCl, in preventing apical extrusion during RCT. The study combines a systematic review of the literature and a case report to illustrate complications associated with NaOCl extrusion.

Materials and Methods

Protocol and Registration

The Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA) guidelines were followed in the conduct of this research (**Supplementary Material**).

Research Processing

The Boolean operator "AND" was utilized in conjunction with the search phrases "apical extrusion, endodontics, irrigant, and sodium hypochlorite" in the databases Scopus, Web of Science, and PubMed to select papers for review. The search was limited to articles published in English between 2004 and 2024. This time frame was chosen to include studies that employ modern techniques, materials, and protocols relevant to current clinical practice (Table 1). The search was conducted between March and April 2024.

Eligibility Criteria

Inclusion criteria:

- Studies conducted exclusively on human subjects.
- Clinical studies or case reports.
- Articles focusing on the analysis and evaluation of irrigation techniques, with a focus on accidental incidents during endodontic therapy.

Exclusion criteria:

- *In vitro* studies.
- Animal studies.

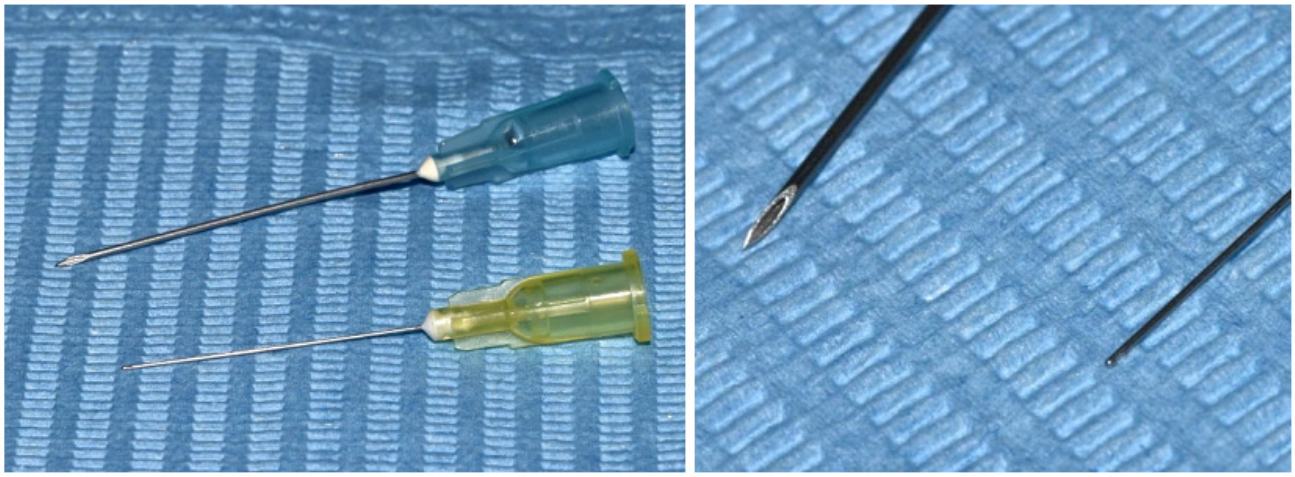

Fig. 2. Endodontic needle. (a) Sterile root canal irrigation needle with blunt tip (blue) and needle with rounded tip and lateral hole (yellow) for endodontic and periodontal washing. (b) A detail of the tips. Although straight irrigation needles like the one shown are commonly used in clinical practice, many practitioners prefer curved or pre-bent needles for improved access and reduced risk of apical extrusion. The selection often depends on canal anatomy and operator preference.

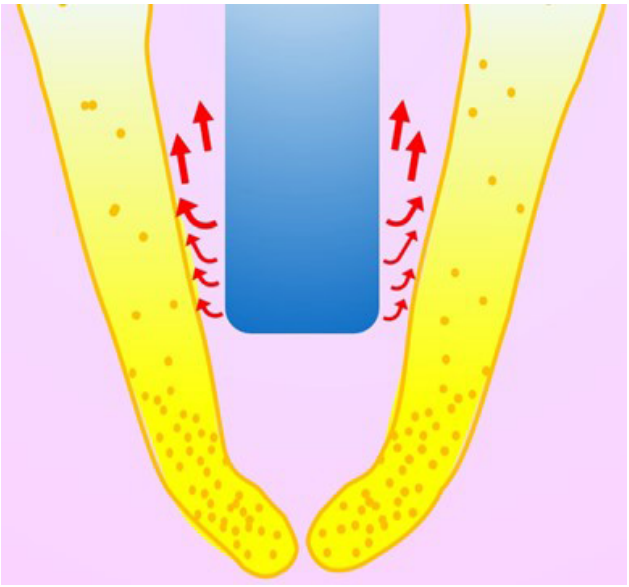

Fig. 3. Schematic diagram showing the function of a side-exit irrigation needle. The arrows represent the lateral direction of irrigant flow, while the blue zone illustrates the low-pressure area preventing apical extrusion. Labels were added for better clarity. The ideal atraumatic tip of the endodontic irrigation needle allows for fluid to escape laterally and not at the tip, thus reducing the pressure that would otherwise be created at the root canal apex. In this way, there is also more space between the needle tip and the canal walls so that there is no escape of irrigant from the tooth apex. Fig. 3 was created by the author using the Microsoft PowerPoint for Microsoft 365 (Version 2408, Microsoft Corporation, Redmond, WA, USA).

• Systematic reviews, narrative reviews, and meta-analyses.

• Studies not relevant to the inclusion topic.

The PICOS criteria used for this review were as follows:
• Population: Adults, both male and female, requiring endodontic therapy.
• Intervention: RCT with NaOCl irrigation.
• Comparison: RCT without NaOCl irrigation.
• Outcome: Effectiveness of endodontic therapy and management of irrigation-related accidents.

Data Processing

Two reviewers independently screened titles and abstracts. Full texts of potentially eligible articles were reviewed for final inclusion. Disagreements were resolved by consensus or by consultation with a third reviewer. Data extraction was performed using a predefined form, collecting information on study design, population, type of injury, NaOCl concentration, treatment, and outcomes. The screening process enabled the exclusion of publications that did not align with the topics under review by examining the abstracts and titles of the articles selected during the identification step. The full texts of articles meeting the inclusion criteria were then reviewed. Disagreements between reviewers regarding article selection were discussed and resolved. The key findings were synthesized narratively and reported in structured summary tables (Tables 2,3, Ref. [13,14,61–67]).

Quality Assessment

The quality of the included articles was assessed by two reviewers, EdR and LF, using the ROBINS-I tool, which is designed to evaluate the risk of bias in non-randomized studies. Reviewers were trained to assess bias in seven domains: confounding, participant selection, intervention classification, deviations from intended interventions, missing data, outcome measurement, and selection of reported results. Disagreements were discussed with a third

Table 2. Qualitative evaluation of studies on NaOCl accidents during endodontic treatment.

Authors (year)	Type of the study	Aim of the study	Materials and methods	Results
Chaugule VB *et al*., 2015 [61]	Case report	To highlight a case of sodium hypochlorite (NaOCl) accident during a pulpectomy in a 4-year-old child, detailing the complication and its management.	During pulpectomy happened a sudden facial swelling occurred due to a NaOCl accident. The incident was managed with copious saline irrigation, medications, and follow-up.	Demonstrate the importance of careful handling of NaOCl during endodontic procedures, especially in pediatric patients, and provide insights into the effective management of NaOCl accidents.
Witton R and Brennan PA, 2005 [62]	Case report	To highlight the potential severe complications associated with the use of NaOCl during endodontic therapy.	Endodontic therapy for an upper right lateral incisor with chronic apical periodontitis. The treatment included the use of a rubber dam and irrigation with NaOCl of the root canal system.	Swelling and pain gradually decreased, with no skin necrosis developing. No surgical intervention was required.
Faras F *et al*., 2016 [13]	Case report	The case underscores the importance of proper handling and immediate management of NaOCl to prevent and treat complications effectively.	During an endodontic treatment, NaOCl was injected with a syringe under mechanical pressure while a rubber dam was placed to isolate the tooth. A chemical burn resulted from the accidental extrusion of NaOCl into the surrounding tissues.	The patient experienced significant healing over time, with the hard palate necrosis healing completely after six weeks.
Singh PK, 2010 [63]	Case study	To present a case report and to review recent literature on the complications, manifestations, and management of NaOCl injection beyond the foramen during root canal treatment (RCT) and incidents.	During an endodontic procedure, pulp extirpation and debridement are performed using ProTaper® rotary files, followed by irrigation with NaOCl.	Immediate pain, swelling, and emphysema followed by delayed bruising, paresthesia, muscle paresis, trismus, and lasting neurological deficits.
Bosch-Aranda ML *et al*., 2012 [64]	Case report	To highlight the potential long-term neurologic injuries caused by NaOCl extrusion and to suggest a treatment protocol for managing these complications.	NaOCl is used as an irrigating solution during RCT. Medications with Sodium diclofenac, Amoxicillin and clavulanic acid, Methylprednisolone, Paracetamol, Omeprazole, Root canal sealers: AH Plus™ root canal sealer chlorhexidine (CHX).	Neurological issues as seen in that require long-term follow-up. Using alternative solutions like CHX can reduce risks, and hospitalization may be necessary for severe cases to ensure better outcomes.
Hatton J *et al*., 2015 [14]	Case report	To highlight the importance of correct management of NaOCl extrusion during RCT, and to discuss the steps needed to reduce the likelihood of severe complications.	Recovery was assessed through clinical criteria, with gradual symptom resolution confirming treatment effectiveness.	The patient made a full recovery without requiring surgical intervention. Significant bruising and swelling were present up to four weeks following the incident.
Özdemir O *et al*., 2022 [65]	Observational Study	To determine the frequency of NaOCl extrusion during RCT and evaluate the outcome of the injury.	Age, gender, medical history, tooth number, preoperative pain, pulpal status, and the presence of periapical radiolucency were recorded.	NaOCl extrusion occurred in 0.89% of cases; 0.18% showed swelling. Acute pain was most common. More visits correlated with symptoms ($p = 0.010$). No severe injuries were reported.
Ajili F *et al*., 2024 [66]	Case Report	To describe the complications associated with NaOCl extrusion during RCT and review the appropriate management strategies for patients who experience such injuries.	Accidental NaOCl (3%) extrusion due to excessive irrigation pressure caused tissue thickening and diffuse emphysema, as confirmed by contrast-enhanced computed tomography (CT).	Symptoms resolved after irrigation with saline, antibiotics, paracetamol, and cold-to-warm compresses, allowing RCT completion.
Salvadori M *et al*., 2022 [67]	Retrospective analysis	To evaluate potential risk factors, symptom management, and clinician responses following these accidents.	Patients' symptoms were documented, and treatments were applied. Standardized data collection was emphasized to better understand and manage these accidents.	Significant symptom improvement was observed within 5–6 days. Apical fenestration and other anatomical features were identified as potential risk factors.

Table 3. Clinical details and management of NaOCl accidents in endodontic treatment.

Authors	Concentration of hypochlorite used	Number - Age - Gender of patient	Tooth involved	Type of injury	Treatment and follow-up
Chaugule VB *et al*. [61]	3%	A 4-year-old female.	Upper left 1st and 2nd primary molars.	Sudden spontaneous extraoral swelling extending from the left infraorbital margin to the angle of the mandible, severe pain, crepitus on palpation of the periorbital area, and restricted mouth opening.	Canal irrigation with normal saline to dilute NaOCl. Open dressing and cold compression with ice packs. Prescription of an antibiotic. Endodontic treatment of the affected teeth was re-initiated and completed successfully.
Witton R and Brennan PA [62]	5.5%	A 43-year-old woman.	Upper right lateral incisor.	Severe soft tissue damage and altered sensation in the infra-orbital nerve distribution and weakness in the buccal branch of the facial nerve.	Antibiotics and analgesics, monitoring and medications: intravenous dexamethasone and regular analgesia to manage pain.
Faras F *et al*. [13]	2.6%	A 24-year-old male.	Upper right second molar.	Severe chemical burn, facial numbness, partial necrosis of the hard palate and blackish hard discharge from the nose.	Creams and ointments for the chemical burn. No Surgical Intervention. The patient was monitored closely. External compression with cold packs initially. Steroids to minimize edema, and antibiotics to prevent secondary infections.
Singh PK [63]	not specified	A 49-year-old female.	Single-canal 15 tooth.	Severe burning and pain, swelling of the cheek, emphysema, facial bruising, paraesthesia, paresis of facial muscles, limited mouth opening and persistent neurological deficits.	Treatment included saline irrigation, local anesthesia, antibiotics, and neurotrophic support. Symptoms were monitored, and the tooth was extracted after one year.
Bosch-Aranda ML *et al*. [64]	not specified	Case 1: A 43-year-old female. Case 2: A 53-year-old female.	Case 1: the left upper central incisor. Case 2: the left upper first premolar.	Paresthesia in the nasogenian area. Swelling, hematoma, and tissue necrosis. Potential for severe complications such as anesthesia or paresthesia due to nerve injuries.	Management included saline irrigation, symptomatic drugs, compresses, and the use of CHX. Severe cases required hospitalization or nerve repair.
Hatton J *et al*. [14]	not specified	A 66-year-old female.	Upper right first premolar tooth.	- Right-sided facial swelling. - Bruising. - Pain. There was no nerve injury or involvement of periorbital tissues.	Medications administered included: antibiotic, steroid, and pain management. Cold compresses were applied for the first 24 hours, followed by warm compresses. Follow-up reviews were conducted at 24 hours, 1 week, and 1 month after admission.
Özdemir O *et al*. [65]	2.5%	1000 patients with 1123 teeth. mean age of approximately 36 years.	Single and multi-rooted teeth in the maxillary and mandibular regions.	Acute burning pain, apical bleeding, and swelling due to NaOCl extrusion during RCT. No severe injuries like neurological damage, tissue necrosis, or trismus were observed.	Management: Negative aspiration and irrigation with distilled water. Symptomatic Management: Calcium hydroxide dressing and antibiotics or anti-inflammatory drugs were prescribed based on symptoms. Follow-Up: two and ten days post-extrusion.

Table 3. Continued.

Authors	Concentration of hypochlorite used	Number - Age - Gender of patient	Tooth involved	Type of injury	Treatment and follow-up
Ajili F *et al*. [66]	3%	A 54-year-old female.	Maxillary right first molar.	Facial swelling, ecchymosis, trismus, bruising, and air emphysema.	Immediate anagement included saline irrigation, antibiotics and compresses (cold initially, then warm). The swelling and symptoms resolved within 15 days.
Salvadori M *et al*. [67]	5%	Case A: 59-year-old woman. Case B: 43-year-old woman. Case C: 54-year-old woman. Case D: 50-year-old man.	Case A: Maxillary right lateral incisor (12). Case B: Right maxillary canine (13). Case C: Left maxillary canine (23). Case D: First maxillary premolar (14).	- Intracanal bleeding. - Ecchymosis. - Facial swelling. - Paresthesia (in one case). - Dysphagia (in one case).	Management included antibiotics, paracetamol, NSAIDs, and corticosteroids, along with cold compresses. Symptoms improved significantly within 5–6 days. CHX was used instead of NaOCl in subsequent treatments.

reviewer (FI) to reach a consensus. Additionally, the Joanna Briggs Institute (JBI) Critical Appraisal Checklist for Case Reports was used to evaluate the risk of bias in identified case reports and to decide whether to include or exclude them [68].

Results

Using keyword searches, the Web of Science (11), Scopus (613), and PubMed (100) databases yielded a total of 724 papers. After removing duplicates (a total of 457 articles), 267 articles remained. From these 22 studies were excluded due to their non-compliance with the pre-established inclusion criteria. Following the selection of 9 papers for this study, the screening procedure was completed (Fig. 4, Ref. [69]). Each study's findings were presented in Tables 2,3.

The risk of bias in the included studies is reported in Fig. 5 (Ref. [13,14,61–67]). Regarding the bias due to confounding, most studies have a high risk. The bias arising from measurement is a parameter with a low risk of bias. Many studies have a high low risk of bias due to bias in the selection of participants. Bias due to post-exposure cannot be calculated due to high heterogeneity. The bias due to missing data is low in many studies. Bias arising from the measurement of the outcome is low. Bias in the selection of the reported results is high in most studies. The final results show that 3 studies have some concerns, 2 have a very high risk of bias and 4 have a high risk of bias.

Case Report

The extrusion of NaOCl beyond the apex, also known as a "hypochlorite accident", is a known but rare complication during root canal therapy. The mechanism is primarily related to the toxicity of hypochlorite, but other factors such as concentration, volume, and pressure can exacerbate the consequences of the extrusion. Prompt and appropriate management of these complications is crucial to avoid long-term adverse outcomes [14].

In this case report, we describe the case of a 59-year-old female patient who developed a hematoma and swelling of the soft tissues on the left side of her face following an endodontic treatment. This case report presents a case of acute facial swelling associated with an endodontic treatment, providing insights into clinical management and patient outcomes.

The case report component of this study was conducted in accordance with the ethical principles of the Declaration of Helsinki. Written informed consent was obtained from the patient for the publication of all clinical information and images.

Case Presentation

A 59-year-old woman presented to the emergency department at the Policlinico di Bari on 29 June 2024, with the temporary resin prosthesis cemented from tooth 1.3 to tooth 2.3, complaining of a hematoma and swelling of the left side of her face (Fig. 6). The patient was otherwise healthy, with no known systemic conditions, allergies, or comorbidities. Her medical history was unremarkable. The symptoms began immediately after an endodontic session performed the previous day at her private dentist for tooth 2.3, located in the upper left arch, where a provisional prosthesis was present from teeth 1.3 to 2.3. The patient reported pain and burning an hour after the treatment.

All clinical images included in this article were acquired at the Dental Department of the Policlinico of Bari (Italy). The patient provided written informed consent both for the acquisition of the images and for their use in scientific publications. The procedures were conducted in accordance with the ethical standards of the institutional and national research committee and with the Declaration of Helsinki.

Upon arrival at the emergency department, a computed tomography (CT) scan with and without contrast (Fig. 7) was performed, revealing an apical granuloma of tooth 2.4 and inflammatory thickening of the left maxillary sinus. The facial swelling was attributed to the leakage of the liquids used for endocanal irrigation beyond the apex of tooth 2.3 into the surrounding subcutaneous tissues, with subsequent subpalpebral spread. To resolve the edema, antibiotics and anti-inflammatory therapy were prescribed for 7 days. Although only axial slices were available, these were sufficient to demonstrate the presence and extent of the lesion and were chosen based on their diagnostic clarity at the time of the CT evaluation.

Subsequently, an orthopantomogram (Fig. 8) was performed for further evaluation.

Clinical follow-ups were conducted at 3 (Fig. 9), 11 (Fig. 10), 18 (Fig. 11), 27 (Fig. 12), and 28 (Fig. 13) days after the event, with no additional procedures performed during this period. The treatment consisted of pharmacological management only, including antibiotics (amoxicillin and clavulanic acid) and corticosteroids, which were prescribed at the emergency department visit.

Fig. 9 (Day 3): Initial follow-up showing extensive facial hematoma and edema, with intraoral evaluation under provisional prosthesis.

Fig. 10 (Day 11): Reduction in swelling and partial resolution of facial ecchymosis.

Fig. 11 (Day 18): Further improvement in extraoral appearance, with intraoral healing and confirmation of canal status via periapical radiographs.

Fig. 12 (Day 27): Almost complete regression of soft tissue signs, photographed externally.

Fig. 13 (Day 28): Full clinical resolution, both extraorally and intraorally.

No further endodontic treatment was performed on the affected tooth (2.3), but the adjacent tooth (2.2) was successfully treated later, as shown in Fig. 14 [70].

The case highlights the importance of accurate identification and management of complications during endodontic treatments. The accidental extrusion of canal irrigants be-

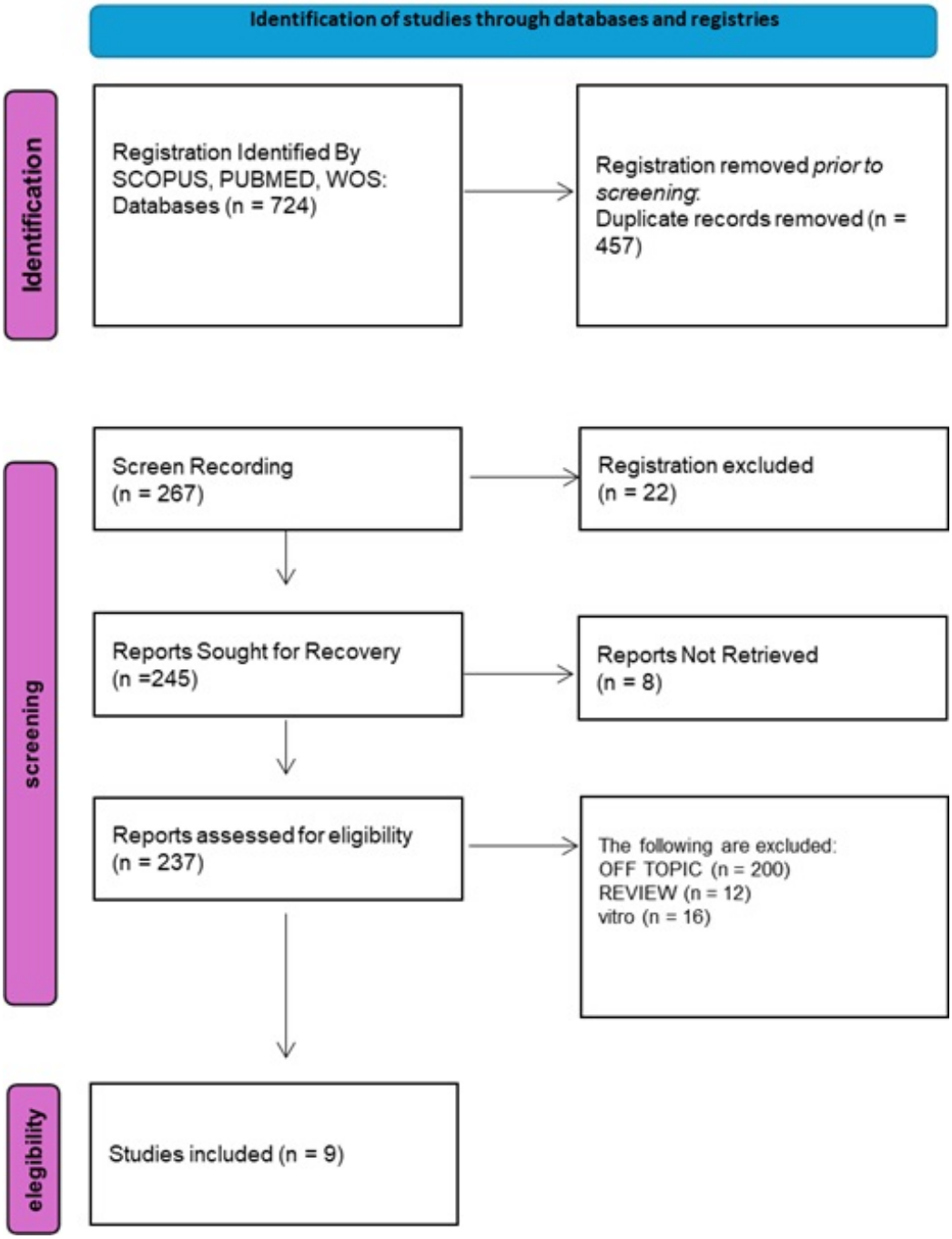

Fig. 4. Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) flowchart [69].

yond the root apex is a well-documented complication, with potential harmful effects on the surrounding soft tissues. Symptoms include facial swelling, hematomas, and, in rare cases, secondary infections and bone necrosis [14,71].

In the presented case, the timely use of CT scanning allowed for the correct diagnosis of the cause of the facial swelling, excluding other potential causes. It is essential that dentists are aware of possible complications and the need for immediate and appropriate treatment [72,73].

In the case report described three possible mistakes that could have caused the hematoma and facial swelling: (1) having injected NaOCl beyond the apex; (2) having closed the canal immediately, in the first session, without allowing the gases, which normally generate from a necrotic canal, to escape to the outside, thus favoring their advancement into the soft tissues and periradicular bone; (3) application in the same session of cemented temporary crown that always involves obstacle to the escape of canal gases [74–76].

Discussion

This review examined the efficacy and risks associated with NaOCl irrigation in endodontics, particularly focusing on

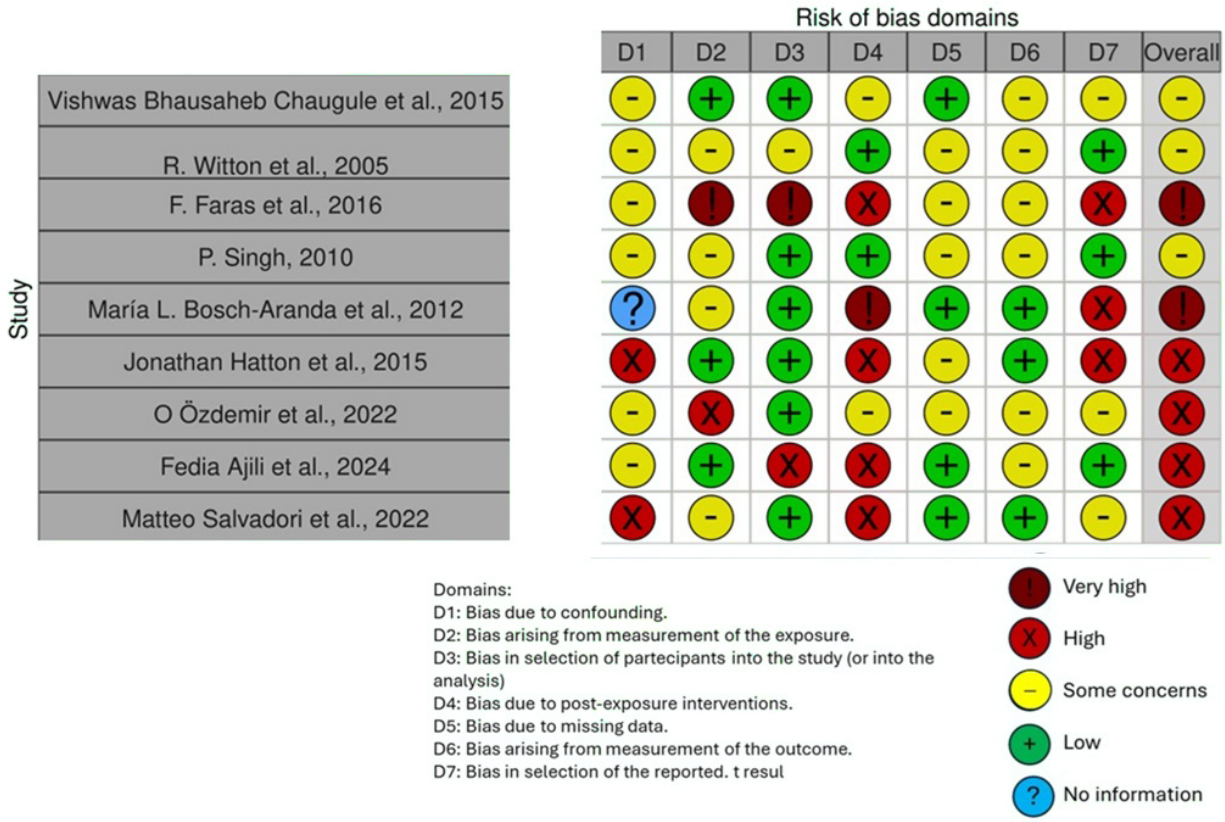

Fig. 5. Risk of bias.

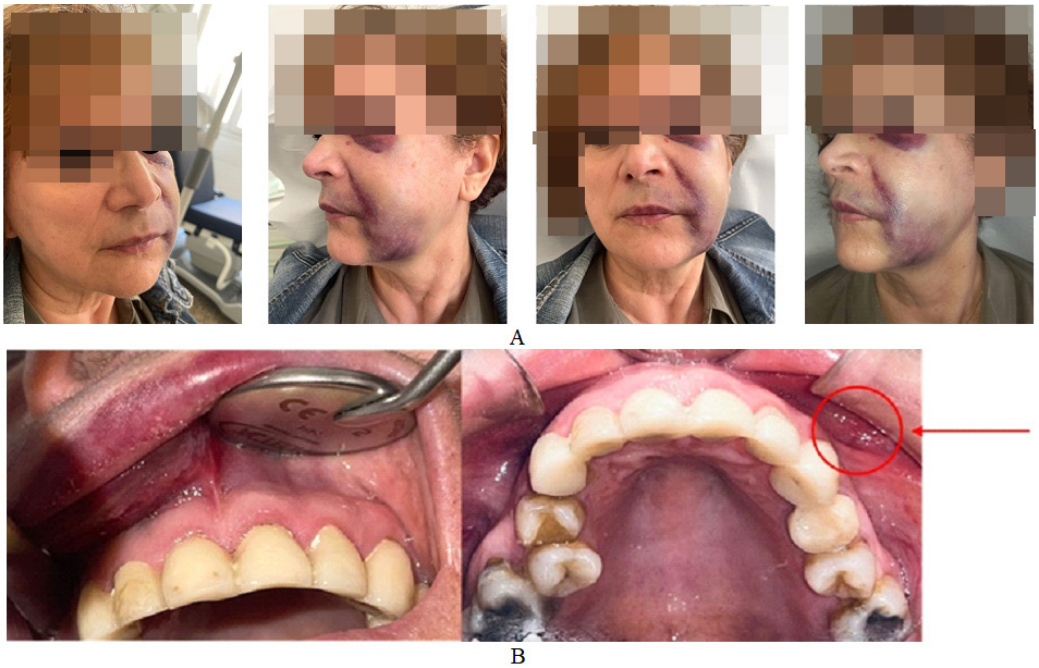

Fig. 6. Extraoral (A) and intraoral (B) photos of the patient dated 29 June 2024. Intraoral photos with provisional prosthesis cemented (red circle).

apical extrusion and its complications. Although the number of clinical reports on this phenomenon is limited, the selected cases consistently reveal shared risk factors, clinical presentations, and treatment strategies. Together with the case report presented, this review aims to contribute practical insights into preventing and managing NaOCl accidents.

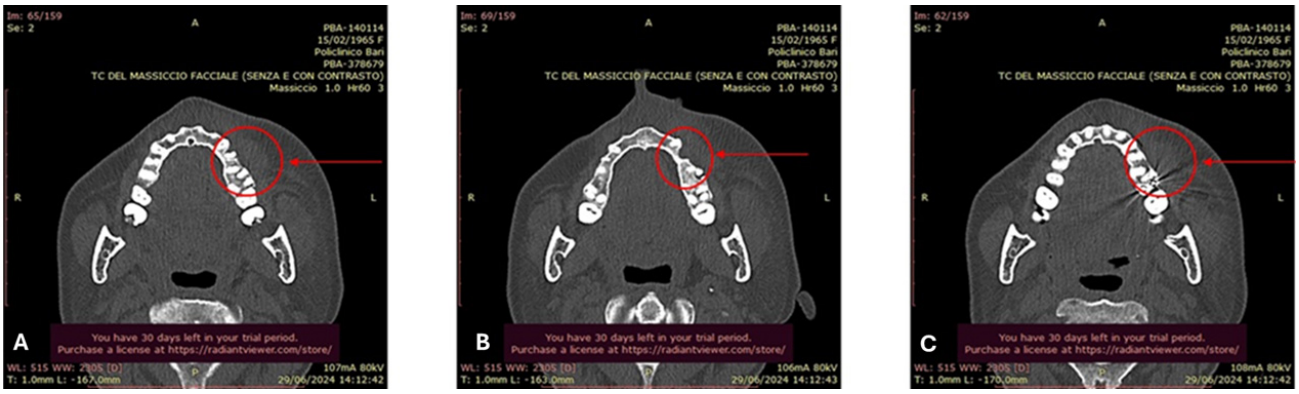

Fig. 7. Axial CT images of the facial bones taken on 29 June 2024, showing soft tissue involvement following apical extrusion of sodium hypochlorite from tooth 2.3. (A) Axial slice showing soft tissue swelling in the left maxillary region, with evident asymmetry compared to the contralateral side (red circle). (B) Enlargement of the periapical region of tooth 2.3, with disruption of trabecular bone pattern and edema extending into adjacent soft tissues (red circle). (C) Continued visualization of the inflammatory process involving the left infraorbital area, consistent with diffusion of irrigant through fascial planes (red circle). L, left; R, right.

Fig. 8. Orthopantomography performed on the patient after the dental session. The red circle shows where the periapical lesion is located.

The research includes a review of current literature and presentation of a clinical case to highlight complications associated with NaOCl extrusion.

A key observation is the occurrence of certain complications, including soft tissue swelling, chemical burns, facial bruising, paresthesia, and in some cases, long-term neurological deficits. These complications appear to be associated with factors such as high irrigation pressure, inaccurate working length, lack of rubber dam isolation, and the use of end-vented rather than side-vented irrigation needles. Several cases also involved anatomical variations such as apical fenestration, which may predispose to extrusion of NaOCl [77].

A 4-year-old girl underwent a pulpectomy for deep carious lesions in her upper left primary molars, during which 3% NaOCl was used for irrigation. Excessive bleeding required extensive irrigation, leading to facial swelling and severe pain due to NaOCl extrusion. Immediate treatment included saline irrigation, cold compresses, and open dressing, with antibiotics, analgesics, antihistamines, and corticosteroids prescribed. The swelling reduced significantly after three days and fully resolved by the seventh day, allowing the completion of the treatment. The case highlights the cytotoxic risks of NaOCl and underscores the importance of careful handling and adherence to safe procedures to prevent such complications [61].

A case analyzed by Witton R and Brennan PA in 2005 [62] has as its protagonist a 43-year-old woman who experienced severe facial pain and swelling after endodontic therapy for chronic apical periodontitis, which involved irrigating her root canal with NaOCl of unknown concentration. Following the procedure, she developed intense pain and swelling, prompting an emergency visit. Examination revealed facial swelling, infra-orbital ecchymosis, and nerve weakness. She was treated with intravenous steroids and antibiotics, resulting in gradual improvement without sur-

Fig. 9. Extraoral (A) and intraoral (B) photos of the patient at the follow-up 3 days later, 2 July 2024.

Fig. 10. Extraoral (A) and intraoral (B) photos of the patient at the 11-day follow-up after the event, dated 10 July 2024.

Fig. 11. Extraoral (A) and intraoral (B) photos and intraoral radiographs of teeth 2.2 to 2.6 in different projections (C) of the patient at the 18-day follow-up after the event, dated 17 July 2024.

Fig. 12. Extraoral photos of the patient at the 27-day follow-up after the event, dated 26 July 2024

gical intervention. This case highlights the potential complications of NaOCl extrusion, emphasizing the need for caution and urgent care in similar incidents [62].

NaOCl, as already mentioned, is a common irrigant used in RCT due to its strong antibacterial and tissue-dissolving properties. However, its use can lead to serious complications, as seen in a clinical case, reported by Faras F *et al.* [13] of a young male who suffered a severe chemical burn and partial palate necrosis after NaOCl extruded during his dental procedure. The patient was treated for a facial burn with topical creams and showed significant recovery, though he was left with some facial discoloration.

Fig. 13. Extraoral (A) and intraoral (B) photos of the patient at the 28-day follow-up after the event, dated 27 July 2024.

Fig. 14. Endodontic sequence of treatment 2.2. (1) canal of element 2.2 with initial dressing, (2) canal being instrumented on 18 July 2024, (3) canal closure on 26 July 2024.

This case highlights the importance of taking precautions during NaOCl use to prevent such accidents, emphasizing early recognition and management to minimize tissue damage and avoid life-threatening situations. Proper use of protective barriers, gentle irrigation techniques, and immediate treatment of NaOCl exposure are crucial to ensuring patient safety [13].

Singh PK's study [63], published in the South African Dental Journal in 2010, focuses on the complications arising from the use of NaOCl as an irrigant in RCT. The case reported by Singh details an incident involving a dentist who experienced significant facial swelling and nerve damage after a NaOCl accident, resulting in persistent paraesthesia and paresis. This highlights a lack of consensus on treatment protocols and the importance of preventive measures during procedures to minimize risks. The study underscores the need for dental practitioners to stay updated with the latest techniques and tools to prevent such accidents [63].

Bosch-Aranda ML *et al.* in 2012 [64], discussed two cases where accidental NaOCl extrusion occurred, highlighting the clinical features, treatment approaches, and possible neurological effects. Both cases showed different severity and outcomes, with one patient experiencing persistent paresthesia. The paper emphasizes the importance of proper techniques to prevent such accidents and suggests guidelines for managing them if they occur [64].

Hatton J *et al.*'s article [14] describes a case of a NaOCl accident during an RCT on a 66-year-old woman, leading

to significant facial swelling and bruising. The incident occurred due to a suspected iatrogenic perforation while treating the upper right first premolar. The patient was admitted to the hospital, where she received intravenous antibiotics, analgesics, and steroids, but did not require surgery. A comprehensive recovery plan, including compresses and regular follow-ups, resulted in a full recovery within a month, though significant bruising and swelling persisted for four weeks. This case underscores the importance of proper management and swift action to prevent severe complications from such accidents [14].

The study of Özdemir O *et al*. [65] investigated the frequency and outcomes of NaOCl extrusion during RCT in 1123 teeth. It found a 0.89% rate of NaOCl extrusion, with 0.18% causing injury. Extrusion led to acute pain, bleeding, and swelling, but no severe injuries like tissue necrosis were reported. The research highlighted the importance of immediate negative aspiration and irrigation to prevent severe injuries. The findings suggest that multiple treatment visits might increase the risk of accidents, underscoring the need for careful procedural management [65].

A recent transcribed case report by Ajili F *et al*. [66] discusses a case where a 54-year-old woman experienced complications following the use of 3% NaOCl during an RCT on her upper right first molar. The patient presented with significant swelling, bruising, and pain due to the extrusion of the irrigant. Immediate treatment involved saline irrigation, antibiotics, and pain management. Over the course of 15 days, her symptoms resolved, allowing for the continuation and completion of the endodontic treatment. The article emphasizes the importance of cautious handling of NaOCl due to its cytotoxicity and outlines preventive measures and management strategies for similar incidents [66].

The Salvadori M *et al*.'s study [67] reports four cases of NaOCl extrusion accidents in maxillary RCT, characterized by symptoms like intracanal bleeding, ecchymosis, and facial swelling. The accidents were managed with antibiotics, analgesics, and steroids, and symptoms generally improved within 5–6 days. Risk factors identified include anatomical features such as apical fenestration and large foramina. The study emphasizes the need for standardized reporting of hypochlorite accidents to improve understanding and management of these events, suggesting that better documentation could help identify risk factors and inform treatment approaches [67]. Across the cases reviewed, the immediate management of NaOCl accidents typically included saline irrigation, systemic corticosteroids, antibiotics, and cold compresses, often followed by warm compresses to aid healing. Most cases showed a favorable resolution, especially when early intervention was provided. For example, both Faras F *et al*. [13] and Hatton J *et al*. [14] emphasize that rapid, supportive treatment can prevent long-term sequelae. Furthermore, some authors suggest replacing NaOCl with alternative irrigants such as chlorhexidine (CHX) in subsequent sessions, particularly when extrusions occur in areas with open apices or patients showing adverse reactions. Salvadori M *et al*. also highlight the importance of standardized reporting and documentation of hypochlorite accidents to improve prevention and develop evidence-based protocols [67].

Dental professionals must be aware of the potential complications of NaOCl extrusion, such as severe pain, swelling, and long-term neurological damage. It is crucial to use careful techniques, such as determining accurate working lengths and using appropriate irrigation needles, to avoid extrusion into periapical tissues. In case of accidental extrusion, immediate intervention with sterile saline irrigation and pain management is essential [62,63,66]. Cold packs and medications can help manage swelling and pain. Some complications might require long-term management and follow-up. For future treatments, using alternatives like CHX in cases of open apex or suspected allergies to NaOCl can reduce risks. In severe cases, hospitalization may be necessary for close monitoring and administration of intravenous medication to improve outcomes. By following these guidelines, dental professionals can reduce the risk of serious complications and ensure better patient outcomes during RCTs [78,79]. While this review is limited by the small number of eligible studies and by the absence of randomized trials, the consistency of reported outcomes across different clinical settings strengthens the conclusions. The collective findings underline that most NaOCl extrusion incidents are preventable, and that early diagnosis and appropriate intervention are crucial for minimizing complications. These studies should focus on the effects of irrigants in complex canal anatomies and varied patient populations, offering evidence for best practices [80]. Clinicians should prioritize safe irrigation techniques, including accurate working length determination, side-vented needles, and the use of rubber dams [81]. Alternatives such as chlorhexidine may be considered in high-risk cases. Consistent reporting of hypochlorite accidents is also key to improving prevention and developing standardized protocols [82]. This review is limited by the small number of clinical studies and the lack of randomized trials. Additionally, the case report reflects a single scenario and may not represent the full spectrum of clinical outcomes.

Future studies, especially controlled clinical trials, are essential to refine irrigation protocols, assess alternative irrigants, and better understand patient-specific risk factors. Despite limitations, this review supports practical recommendations to enhance patient safety in endodontics.

Based on the reviewed literature, the management of NaOCl extrusion complications generally includes immediate irrigation with sterile saline, administration of systemic antibiotics and corticosteroids, and symptomatic relief using cold compresses in the acute phase, followed by warm compresses to promote healing [13,14]. In severe cases, hospitalization and close monitoring may be necessary. Early intervention and tailored pharmacological sup-

port appear to be key to preventing long-term complications. These approaches, although variably applied across cases, represent the core of currently accepted clinical management strategies. Although the number of studies included in this review is limited, the consistency in clinical patterns, risk factors, and therapeutic approaches allows for the development of practical recommendations to enhance patient safety during root canal therapy. To complement the evidence emerging from the systematic review, we present below a clinical case of NaOCl extrusion, which exemplifies the real-life presentation and management of this complication.

Conclusions

Root canal irrigation is crucial for cleaning and disinfecting the root canal system, with NaOCl being the gold standard due to its antimicrobial properties. However, NaOCl can cause serious complications if mishandled, such as chemical burns and tissue damage. Safety measures, including precise irrigation techniques, rubber dams, and side-exit needles, are essential to minimize these risks. The manuscript stresses the need for further research to optimize irrigant use and improve patient safety. Effective endodontic treatment relies on careful irrigant selection, timely management of complications, and collaboration between dental professionals to ensure the best patient outcomes. Although the number of studies included in this review is limited, the consistency in clinical patterns, risk factors, and therapeutic approaches allows for the development of practical recommendations to enhance patient safety during root canal therapy.

Availability of Data and Materials

The data used and analyzed during the current study are available from the corresponding author on reasonable request.

Author Contributions

Conceptualization: ADI, AMI, FI, AP and LF; methodology: LF; software: GDV; validation: FI and EdR; formal analysis: EdR, ADL; investigation: GDV, AP and FI; resources: LF, GD and AMI; data curation: AMI, LF, ADI, GD, EdR, AP and FI; writing—original draft preparation: LF, EdR, ADI, ADL and AMI; writing—review and editing: GDV, ADI and AP; visualization: GD; supervision: ADL, LF, FI, and GDV; project administration: FI. All authors contributed to the critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

Not applicable.

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Conflict of Interest

The authors declare no conflict of interest.

Supplementary Material

Supplementary material associated with this article can be found, in the online version, at https://doi.org/10.62713/aic.4139.

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