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Review Article

A Scoping Review on the Management of Root Fractures in Primary Teeth

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ABSTRACT

Traumatic injuries to teeth are a prevalent global health concern, with primary front teeth in young children being particularly susceptible. Early management is essential, as losing primary teeth prematurely can negatively impact both appearance and function. While extrusion, lateral luxation, and intrusion are the most frequently observed injuries, root fractures are relatively rare but may lead to extraction if not correctly identified and treated. Limited evidence exists regarding strategies for managing root fractures in primary teeth. This review examines the current understanding of their treatment and proposes a practical clinical approach based on existing findings. Searches were conducted in Web of Science, PubMed/MEDLINE, and SCOPUS, focusing on patient age, fracture location, type of displacement (intrusive, extrusive, lateral), emergency or diagnostic interventions performed, adherence to IADT guidelines, and follow-up periods. Only eight studies met the inclusion criteria, reporting on 46 patients with 62 root fractures. Among upper incisors, splinting was the most common management approach (n = 39), with durations ranging from three weeks to three months, averaging six weeks. No intervention was applied in 23 fractures. Most cases employed semi-rigid splints fixed with composite resin, while a single study used an orthodontic splint with brackets and 0.5 mm stainless steel wire. Although uncommon, root fractures in primary teeth may cause complications such as delayed or altered eruption of permanent teeth. Conservative treatment, including accurate radiographic assessment, immediate repositioning, and semi-rigid splinting, can help preserve the affected teeth and reduce the risk of premature loss in young children.

Keywords: Dental trauma, Pulp injuries, Children, Orthodontic splint, Dental traumatology, Primary root Fracture

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Introduction

Primary teeth play a crucial role both functionally, by guiding the eruption of permanent teeth, and aesthetically [1]. Traumatic dental injuries (TDIs) significantly affect the quality of life of children and their families, as reported in multiple studies [2-4]. Epidemiological research indicates a high incidence of TDIs, estimated around 50% [5, 6], a figure recently confirmed by meta-analytical data [7], highlighting their status as a significant global health issue. Injuries to primary teeth can also have lasting effects on the developing permanent dentition [8], with the highest risk occurring within the first two years of life due to the close proximity of the roots of the maxillary primary incisors to the permanent tooth germs [9]. Often, these injuries go unnoticed or are underestimated by parents, who may be unaware of the potential consequences for the permanent teeth.

Dental emergencies involving TDIs, as outlined in the International Association of Dental Traumatology (IADT) Guidelines [10], are a source of considerable stress and anxiety for both children and their caregivers

[10]. These events frequently coincide with a child's first dental visit, further complicating management for the dental team [10]. Traumas such as extrusive luxation, root fractures, and alveolar fractures may also cause painful occlusal interference, necessitating prompt intervention [10]. Left untreated, such injuries can result in premature tooth loss, potentially disrupting the eruption and alignment of permanent teeth [11]. Consequently, dentists have a vital role in managing TDIs in primary teeth.

Maxillary central incisors are the most commonly affected teeth, accounting for up to 80% of cases [12]. While extrusion, lateral luxation, and intrusion are the predominant injuries, root fractures are relatively rare, with an incidence of approximately 2% [13]. These fractures usually result from severe trauma near the cervical portion of the crown or within the alveolar bone [14]. Root fractures are classified according to the location of the fracture line—apical, middle, or coronal third—and further distinguished as subcrestal or supracrestal [15]. Clinical presentation can vary, ranging from mild to severe, and differential diagnosis often includes extrusive luxation.

Examination may reveal swelling in the vestibular alveolar region and increased mobility of the affected teeth. Radiographic evaluation is essential for diagnosis, typically showing a horizontal radiolucent line along the fracture; if the X-ray beam is angled, a double image of the vestibular and palatal sides may appear. Unlike root fractures, extrusive luxation shows an empty or radiolucent alveolar space with lengthened periodontal ligaments and no visible fracture lines [16, 17].

Regarding treatment, many authors advocate extraction of deciduous teeth with root fractures, particularly type 3, often leaving the apical fragment to undergo natural resorption [18]. Conservative approaches may be considered for fractures in the middle or apical thirds, which are more common. These cases are managed with splinting and occlusal stabilization, allowing healing through connective tissue formation despite mobility at the fracture site [19]. Andreasen *et al*. reported a favorable success rate for conservative management as early as 1998, despite challenges in splinting and limited cooperation from pediatric patients [20]. Follow-up requires thorough clinical and radiographic monitoring, focusing on pulp vitality and periodontal status, and paying close attention to complications such as pulp canal obliteration (PCO) and pulp necrosis (PN). PCO involves gradual excessive deposition of tertiary dentin, leading to a progressive reduction in the radiographic appearance of the endodontic canal [21].

The primary aim of this study was to conduct a scoping review to evaluate the diagnostic and therapeutic management of root fractures in primary teeth. The review focused on identifying appropriate clinical and radiographic assessments, therapeutic interventions, and analyzing factors including the presence of additional trauma, tooth displacement, timing of treatment, adherence to IADT guidelines, resorption of apical root fragments, pulp vitality, and follow-up duration.

Materials and Methods

This study employed a scoping review approach, following the methodology first outlined by O'Malley and Arksey [22] and later refined by Zachary Munn and colleagues [23]. The review process consisted of four main steps: defining the research question, identifying relevant literature, selecting studies for inclusion, and extracting and synthesizing the findings. A protocol was designed in accordance with the 2015 PRISMA guidelines for systematic reviews and meta-analyses [24].

Research questions

The aim of this review was to examine existing evidence on the diagnosis and management of root fractures in primary teeth and to determine best practices for clinical and radiographic evaluation and treatment. Specific factors analyzed included: patient age; fracture location; diagnostic procedures employed (such as radiographs, thermal or electric pulp testing, inspection, palpation, and percussion); type of tooth displacement (intrusive, extrusive, or lateral); apical root resorption and timing, assessed via follow-up imaging; emergency interventions including repositioning, splinting, or extraction, and their consistency with IADT recommendations; crown integrity and pulp health outcomes, including the presence of pulp canal obliteration (PCO); post-trauma care recommendations; and duration and findings of follow-up.

The literature search was structured using the PICO framework [25]:

1. Population: Children with primary dentition who experienced root fractures or dislocations (intrusive, extrusive, or lateral) affecting incisors. Fractures of deciduous molars were excluded.
2. Intervention: All emergency therapeutic measures were considered.
3. Comparison: Patient age and involvement of permanent tooth germs were evaluated in relation to the type of injury.

4. Outcomes: The number of root fractures, treatment approach, and healing during follow-up were recorded.

Only studies published in English were included, regardless of publication date. Eligible study types encompassed observational studies, randomized clinical trials, case reports, and case series. Editorials, review papers, in vitro or animal studies, conference abstracts, commentaries, and letters were excluded.

Study selection

The criteria used to determine inclusion and exclusion of studies are summarized in **Figure 1**.

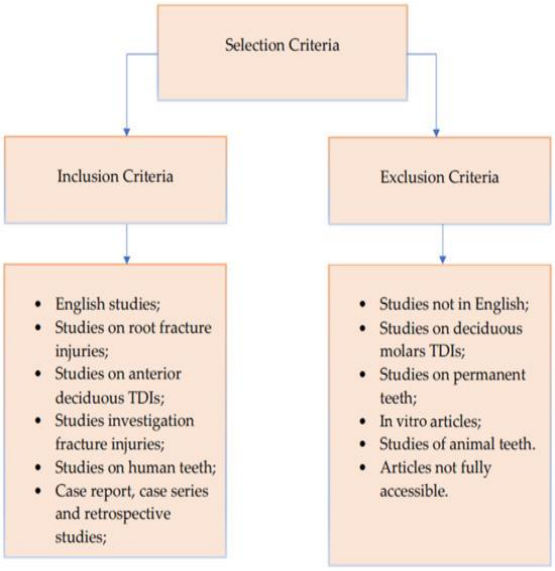

Figure 1. Diagram showing the inclusion and exclusion criteria used for this review.

Search strategy

The literature search for this review was conducted between June and August 2021 using SCOPUS, Web of Science, and MEDLINE/PubMed. The keywords applied included: ((root fracture) AND (tooth OR primary teeth)), ((root fracture) AND (tooth OR deciduous teeth)), and (root fracture) AND (permanent germs). Two independent reviewers (ES and MSM) initially screened titles and abstracts to identify potentially relevant studies, after which they collaborated to create a finalized selection. Discrepancies were resolved by consultation with a third reviewer (NZ).

Study quality assessment

The quality of the included studies was evaluated independently by three reviewers (ES, MSM, and NZ). Inter-reviewer agreement was measured using Cohen's kappa coefficient, yielding a moderate value of 0.60 [26]. Any disagreements were discussed and resolved collectively by all three reviewers to ensure objective evaluation.

Data extraction

The primary reviewers (ES and MSM) extracted key information from each study, including publication year, first author, patient age and sex, number of samples and root fractures, affected tooth, fracture location (apical, middle, or coronal third), any associated trauma such as luxation, developmental stage of permanent tooth germs, time elapsed since trauma, emergency interventions performed, and follow-up duration. All collected data were organized in a Microsoft Excel spreadsheet for subsequent analysis.

Results and Discussion

Characteristics of the included patients

Figure 2 presents the flowchart illustrating the search strategy and study selection process for this scoping review. Only eight studies satisfied all inclusion criteria. Of these, seven were case reports, while one study was a larger retrospective analysis, as summarized in **Table 1**. Across these studies, 46 patients were described, accounting for a total of 62 root fractures: 9 fractures were reported in the case reports, and 53 in the retrospective study. Patient ages ranged between 3 and 4 years. Gender distribution included 12 girls and 34 boys, though one retrospective study reported age ranges rather than mean ages. Most injuries resulted from accidental falls at home, with only a single incident occurring at school. All included cases involved root fractures of the maxillary incisors, and in one instance, both central incisors were affected **(Table 1)**.

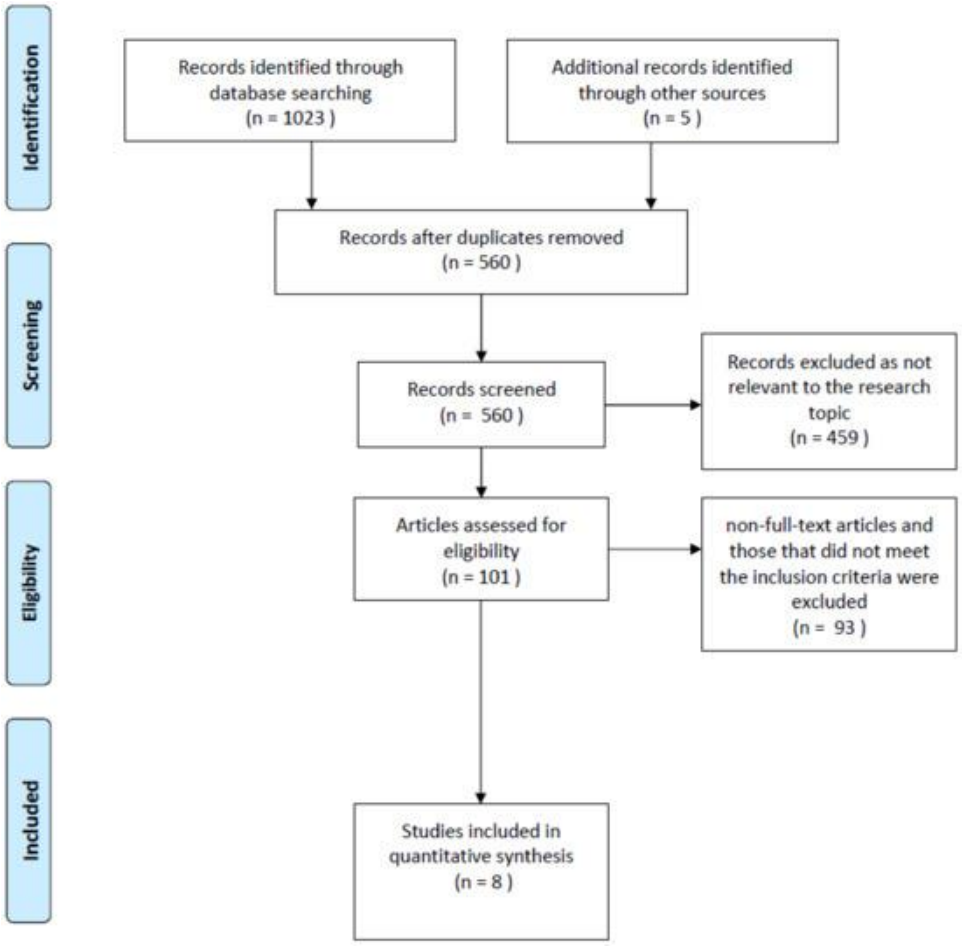

Figure 2. Flowchart of the literature search and selection process.

Table 1. Data from the eight articles included in the review. Legend: AT = apical third; MD = middle third; IPR = intraoral periapical radiograph; M = male; F = female.

Author and Year	Type of Article	N° of Samples	N° of Dental Fracture	Traumatized Tooth	Localization of Fracture	Any Other Trauma	Permanent Germs Maturation Stage	Tests Performed	Range Time after the Detected Trauma	Age	Gender	Therapeutic Intervention	Follow-Up	Outcome
Bonanato *et al*., 2009 [14]	Case report	1	1	61	AT	Extrusive luxation vestibularly	ns	IPR	1 day	3	F	Repositioning and splint (semi-rigid containment with a 0.5 orthodontic wire affixed with photopolymerizable resin) for 3 weeks	12 months	Permanence of the apical fragment and reduction in the separation between the root fragments, no discoloration

Liu *et al*., 2013 [18]	Case report	1	2	51 61	AT MD	Grade II mobility Gum bleeding Extrusive Luxation of 1 mm palatally Grade II mobility Gum bleeding	Crown 3/4 complete	IPR	Same day	3.5	F	Splint (orthodontic brackets and 0.5 mm stainless steel wire) for 3 months. Repositioning and splint (orthodontic brackets and 0.5 mm stainless steel wire) for 3 months	2.5 years	After 3 months the root resorption of both apical fragments was almost completed
Gadicherla *et al*., 2016 [27]	Case report	1	1	51	AT	No mobility	Crown 3/4 complete	IPR	3 days	3.5	F	Any treatment	4 months	No complications
Kumari *et al*., 2017 [28]	Case report	2	1 1	51 51	AT MD	Grade II mobility Grade II mobility	Crown 3/4 complete	IPR	Same day Same day	4 4	M M	Splint (semi rigid wire-composite splint) for 2 months. Splint (semi-rigid wire composite) for 4 weeks	36 months 24 months	Resorption of the apical fragment and apical root after 2.5 years. Resorption of the apical fragment and apical root after 1 year
Bruzda-Zwiech *et al*., 2018 [29]	Case report	1	1	61	AT	Mobility	ns	IPR	Same day	3	M	Any treatment	3.5 years	At the 8-month follow-up there was evidence of healing of the root fracture with calcified tissue, at 3.5 years there was a complete resorption of the apical fragment and of the entire root
Di Giorgio *et al*., 2021 [30]	Case report	1	1	51	AT	Extrusive luxation of 3 mm	ns	IPR	Same day	3,5	M	Repositioning and splint (orthodontic flexible	3 years	After 1 year there was pulp canal obliteration and

												splint) for four weeks		resorption of the apical fragment
Cho *et al*., 2017 [31]	Retrospective study	38	53	ns	ns	ns	ns	ns	<24 h 14 >24 h 19	ns	30 M 8 F	Any treatment: 20 Splinting: 33	6 months	Any treatment: failure 14 Splinting: failure 11

Root fracture classification

Within the case reports, six fractures were identified in the apical third of the root [14, 18, 27-30], and three occurred in the middle third [18, 28, 32]. In the larger retrospective study by Cho *et al*., the precise location of fractures was not detailed, though all involved either the middle or apical third [31].

Associated trauma and displacement

The most frequently observed facial injuries were lip swelling and bleeding, noted in five cases, while two patients showed no soft tissue damage. Tooth mobility was documented in four cases; two were classified as grade II by Kumari *et al*. [28], and one by Liu *et al*. [18], while Brudza-Zwiech *et al*. reported mobility without specifying severity [29]. Luxation injuries were also present in some instances: Bonanato *et al*. described a vestibular extrusion [14], Liu *et al*. reported a 1 mm palatal displacement [18], and Di Giorgio *et al*. observed a 3 mm extrusion [30]. In Cho *et al*.'s retrospective cohort, it was unclear whether any fractures coincided with luxation [31].

Timing of intervention

Most patients (n = 20) received treatment within the first 24 hours following trauma, while one case was managed three days later. In the retrospective study by Cho *et al*., 19 children were treated within a day of injury [31]. Flores *et al*. did not provide specific information regarding the interval between trauma and intervention [32].

Diagnostic procedures

All cases utilized periapical radiographs for initial assessment, which proved crucial for diagnosis. Radiographs were repeated during follow-ups, with an average of three images per patient; Liu [18] and Brudza-Zwiech *et al*. [29] documented up to five radiographs per case. Percussion testing was commonly performed at baseline, showing positive responses at the time of trauma and negative results during follow-up assessments.

Treatment modalities

Of the 62 fractures reviewed, splinting was the most frequently applied intervention (n = 39), with duration ranging from three weeks to three months, averaging six weeks. Twenty-three fractures received no treatment. Among the case reports, seven teeth underwent splinting, and two were left untreated. In Cho *et al*.'s study, 33 fractures were stabilized with splints, while 20 were untreated [31]. Semi-rigid splints bonded with composite resin were most commonly used; one study applied an orthodontic splint with brackets and 0.5 mm stainless steel wire [18], and Di Giorgio *et al*. preferred a flexible splint [30]. The majority of interventions adhered to IADT guidelines.

Follow-up protocols

Follow-up periods varied from four months to 3.5 years. Five teeth were monitored until the eruption of permanent incisors, showing no adverse outcomes. Typically, a second check-up was scheduled 2–4 weeks after the initial visit, followed by longer intervals of six months to one year, in line with IADT recommendations.

Discussion

Root fractures in primary teeth are uncommon, occurring most frequently in children aged 3 to 4 years, a period coinciding with the onset of physiological rhizolysis [28]. As observed in the cases analyzed in this scoping review, these injuries are typically the result of falls or accidental trauma during early childhood play, either at home or during sports activities [28]. Consistent with previous literature, maxillary central incisors are the teeth most often affected [10].

Managing root fractures in primary dentition presents significant challenges for clinicians, not only due to diagnostic and treatment complexities but also because TDIs can cause emotional stress for both the child and family. Patient cooperation is particularly critical for successful conservative management [29]. Periapical radiographs were consistently utilized in all included cases for diagnostic purposes, in line with IADT recommendations [10]. Most fractures were located in the middle or apical third of the root, confirming

literature reports. Overall, the majority of cases adhered to IADT guidelines, with teeth that were mobile or involved in luxation trauma undergoing splinting and subsequent monitoring.

Splinting serves a dual purpose: it protects the injured tooth from further trauma and stabilizes the supporting tissues to facilitate periodontal fiber healing [33]. Andreasen *et al*. also emphasized the importance of timely management of TDIs in primary teeth to prevent additional damage [34]. Out of 62 fractures, 23 were not splinted [27, 29]. In the study by Gadicherla *et al*., this approach was justified because the affected teeth exhibited no mobility [27]. Conversely, in Bruzda-Zwiech *et al*., teeth showing mobility were left untreated, which did not comply with IADT recommendations [29].

Semi-rigid splints bonded with composite resin were the most commonly applied method in the reviewed cases [14, 28, 30, 32]. Only one study utilized an orthodontic splint with brackets and 0.5 mm stainless steel wire [18]. Liu *et al*. highlighted that this type of splint is particularly suitable for very young children, as it is easier to place and allows ongoing assessment of tooth mobility without removing the brackets [18]. In Cho *et al*.'s retrospective analysis of 182 luxated primary teeth, 90 were stabilized with semi-rigid flexible wire splints. The study demonstrated that splinting significantly improved outcomes: splinted teeth were 4.67 times more likely to achieve clinical success compared with non-splinted fractured teeth [31].

Splinting not only protects the tooth but also helps prevent further trauma, while allowing limited functional movement of the injured teeth [35]. Literature shows that rigid splints can lead to tooth immobilization and increase the risk of ankylosis, whereas flexible splints are associated with higher healing rates [35]. Flexible splints, typically composed of stainless steel wires 0.3–0.4 mm in diameter combined with composite resin, offer multiple advantages: ease of placement, suitability for uncooperative pediatric patients, maintenance of oral hygiene, minimal interference with aesthetics, speech, or mastication, and no obstruction for pulp vitality testing or other dental procedures [35].

The duration of splinting varied across studies, often exceeding IADT recommendations [14, 18, 28]. According to the latest guidelines, flexible splinting is advised for four weeks, while fractures near the cervical region may require stabilization for up to four months [10].

In terms of managing teeth with root fractures, none of the cases analyzed in this scoping review received pulpotomy or pulpectomy treatment. Additionally, intraoral radiographs revealed no periapical lesions in any of the examined cases. The only exception was the study by Di Giorgio *et al*., where a case of pulp canal obliteration (PCO) without associated coronal discoloration was observed during a one-year radiographic follow-up [30]. PCO is defined by the progressive and excessive formation of tertiary dentin along the canal walls, which appears radiographically as a reduction in the endodontic space [36]. Literature reports, such as those summarized by Santos *et al*., indicate that the prevalence of PCO varies widely, ranging between 3% and 48% [21]. A retrospective analysis of 112 primary maxillary incisors with a nine-year follow-up found PCO in 54% of trauma cases, typically within the first year, with no observed link to secondary pulp necrosis [21]. Therefore, the absence of documented PCO in the cases included in this review—except for one instance—may reflect underdiagnosis, insufficient radiographic follow-up, or the fact that PCO was not considered among the inclusion criteria for these studies.

Proper disinfection of the injured site, maintenance of oral hygiene, and a balanced diet are all crucial for the healing of traumatized teeth [37]. Many studies recommend chlorhexidine-based mouth rinses [18, 27, 29] or topical application with soft brushes [30]. A soft diet was also consistently advised to minimize the risk of additional trauma. Clear and concise guidance to parents is essential to ensure their cooperation and support optimal healing.

Concerning follow-up outcomes, resorption of the apical root fragment occurred in nearly all cases except two. This type of resorption typically manifests relatively quickly, often within three months, as reported by Liu *et al*. [18]. It is hypothesized that the trauma stimulates osteoclast activity, although the exact mechanisms remain unclear [38, 39]. Nam *et al*. classify apical fragment resorption in primary teeth as a form of atypical resorption (ARR) [40], characterized radiographically by circumferential resorption along the lateral and/or apical surfaces of primary maxillary incisors [40]. Radiographic assessment is therefore key for diagnosis. ARR can be differentiated from inflammatory resorption by the absence of periapical bone radiolucency and the distinct bowl-like morphology of the affected root. None of the cases in this review reported any adverse effects on the developing permanent tooth germ, consistent with existing literature [10, 41]. The preservation of the permanent germ is attributed to the apical fragment remaining in its original position, while the coronal fragment is displaced along the periodontal ligament

and neurovascular bundle due to trauma [42]. Consequently, careful repositioning and splinting of the coronal fragment do not compromise the permanent tooth germ [42]. These findings underscore the advantages of conservative management for primary root fractures. Supporting this, a Brazilian retrospective study of 351 children aged 1–4 years highlighted that close monitoring is the preferred management strategy for traumatic dental injuries (TDI) in primary teeth, even in severe cases [43].

The results of this scoping review raise several important clinical considerations:

- Root fractures in primary teeth are uncommon injuries, mainly affecting the maxillary incisors in children aged three to four years. If not properly managed, these fractures can lead to complications such as premature tooth loss, disruption in the eruption of permanent teeth, and potential psychological impacts.
- At the initial diagnostic stage, particular attention should be given to the interpretation of radiographs, especially regarding early resorption of the apical fragment, which generally represents a normal physiological response.
- Concerning management, repositioning and splinting of the coronal fragment do not harm the developing permanent tooth germ [42]. This protective effect occurs because the apical fragment remains in its original position. Consequently, conservative approaches to primary tooth root fractures are highly advantageous. Repositioning combined with semi-rigid splinting can serve as a non-extractive treatment strategy in pediatric patients.
- Immediate manual repositioning of the displaced coronal fragment followed by splinting has shown favorable long-term outcomes. Although the use of orthodontic splints is scarcely described in the literature, they may be a valuable alternative when manual repositioning is challenging, warranting further investigation.
- Pulp canal obliteration (PCO) in teeth affected by root fractures is common and should not be interpreted as pathological. This physiological pulp response is often under-recognized or insufficiently evaluated in clinical research.

Conclusion

This scoping review demonstrates that most of the primary objectives were addressed, although some included studies did not fully examine all research questions. The data collection methods lacked consistency across studies. Therefore, standardizing the diagnostic and therapeutic approach, with particular emphasis on radiographic evaluation, is recommended. Further clinical research with larger sample sizes and comprehensive data collection is essential to support systematic reviews and enable meta-analyses of the therapeutic strategies discussed in this review.

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