GRADUATION PROJECT

Degree in Dentistry

Cracked Tooth Syndrome

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RESUMEN

Introducción: El síndrome del diente fisurado (Cracked Tooth Syndrome, CTS) es una patología frecuente en odontología restauradora y endodoncia, caracterizada por fracturas incompletas cuya detección resulta compleja debido a la variabilidad de los síntomas y a las limitaciones de los métodos diagnósticos actuales. **Objetivos**: Analizar los mecanismos etiopatogénicos del CTS, identificar los criterios diagnósticos más fiables y evaluar la eficacia de las estrategias terapéuticas actuales con el fin de optimizar el pronóstico clínico. **Metodología**: Se realizó una revisión de la literatura científica basada en la búsqueda en bases de datos relevantes, aplicando criterios de inclusión y exclusión previamente definidos. Se analizaron los estudios seleccionados en función de los métodos diagnósticos, los factores etiológicos y las opciones terapéuticas descritas. **Resultados**: Los resultados muestran que el CTS tiene un origen multifactorial, en el que intervienen factores mecánicos, biológicos e iatrogénicos. El diagnóstico se basa en la combinación de exploración clínica e imagen, sin que exista una prueba única fiable. Las restauraciones adhesivas indirectas y, en casos avanzados, el tratamiento endodóntico seguido de protección cuspídea constituyen las opciones terapéuticas. **Conclusiones**: El CTS sigue siendo un desafío diagnóstico y terapéutico. La detección precoz y el enfoque conservador son fundamentales para mejorar el pronóstico y preservar la estructura dental.

PALABRAS CLAVE

Odontología; diagnóstico; diente; fisura; fractura; pronóstico; síndrome

ABSTRACT

Introduction: Cracked Tooth Syndrome (CTS) is a common condition in restorative dentistry and endodontics, characterized by incomplete tooth fractures whose detection remains challenging due to variable symptoms and limitations of current diagnostic methods. **Objectives**: To analyse the etiopathogenic mechanisms of CTS, identify reliable diagnostic criteria, and assess the effectiveness of current therapeutic strategies in order to optimise clinical outcomes. **Methods**: A literature review was conducted using relevant scientific databases, applying predefined inclusion and exclusion criteria. Selected studies were analysed according to diagnostic methods, etiological factors, and treatment approaches. **Results**: CTS has a multifactorial origin involving mechanical, biological, and iatrogenic factors. Diagnosis relies on a combination of clinical examination and imaging, as no single method is fully reliable. Indirect adhesive restorations and, in advanced cases, endodontic treatment followed by cuspal coverage represent the main therapeutic approaches. **Conclusions**: CTS remains a diagnostic and therapeutic challenge. Early detection and conservative management are essential to improve prognosis and preserve tooth structure.

KEYWORDS

Dentistry; diagnosis; fissure; fracture; prognosis; syndrome; tooth

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1 INTRODUCTION

1.1 Definition and Context

Cracked tooth syndrome (CTS) refers to a partial fracture of the tooth structure, usually found on the posterior teeth, extending from the enamel to the dentin and sometimes to the pulp or periodontal ligament (1–3). Cameron was the first to describe it in 1964, associating it with intense pain during chewing and complications related to diagnosis (2,4).

CTS remains one of the most common causes of tooth loss after caries and periodontal disease (3,5). Epidemiological research indicates that CTS mainly affects the mandibular molars and first maxillary molars, which are exposed to the highest occlusal stresses (3–5). This syndrome is more common in individuals over the age of 40 (6), presumably due to progressive dentin wear and changes in occlusal morphology (3,5).

The American Association of Endodontists (AAE) identifies five major categories of longitudinal fractures: craze lines, fractured cusps, cracked teeth, split teeth, and vertical root fractures (2,4) the cracked tooth itself represents the most the common clinical sign of CTS among the various manifestations. Patients often report intense, sharp and transient pain when chewing or when releasing pressure during mastication, sometimes associated with sensitivity to cold (2,7,8). Diagnosis is often complicated and delayed due to the sporadic and vague nature of these symptoms (2,8,9). Clinical decision-making for cracked teeth also varies significantly among practitioners, reflecting the absence of universally accepted diagnostic and treatment protocols(10). There has also been an increase in incidence in recent years, which may be associated with bruxism and increased stress behaviors since the COVID-19 crisis (3). This trend highlights the need for earlier detection of cracks in everyday clinical practice.

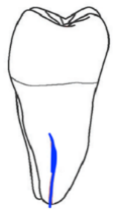
Craze Line (superficial crack):	These are very small superficial cracks limited to the enamel. They do not weaken the tooth and do not compromise its overall structure. (10)	
Cracked Tooth (CT):	In this case, the crack extends beyond the enamel and reaches the dentin. Its actual depth or length is often difficult to determine and, in some cases, it may even extend below the bone crest toward the root. The pulp might or not be affected. (10)	
Cracked or fractured cusp:	Molars: The cusp may have a partial or complete fracture along a buccal or lingual groove, often in the mesio-distal direction. Premolars: these fractures tend to affect the marginal ridges. The pulp might or not be affected.(10)	
Vertical root fracture (VRF):	This is an incomplete longitudinal crack in the root that extends through the dentin and cementum and may reach the canal space. (10)	
Split root:	This is a more advanced form of vertical root fracture, where the root is completely divided into several distinct segments.(10)	

Figure 1: *Classification of CTS according to the American Association of Endodontists (AAE)*

1.2 Dental Anatomy and histology

In order to understand CTS we need to apprehend the complex histological structure of a tooth which is linked to its biomechanical integrity. Enamel, which consists of approximately 96% hydroxyapatite, is hard and brittle, while the dentin underneath is softer more flexible and resilient(11). Dentino-enamel junction (DEJ) is a crucial interface that absorbs and redistributes functional stresses (2,12) located between the two. However, repeated masticatory forces can cause microcracks initiated at the DEJ and that accumulate due to differences in stiffness between enamel and dentin (1,5). Once initiated, these cracks often propagate in a mesio-distal direction through the dentin, following lines of structural weakness and areas of stress concentration under the influence of everyday loading cycles (3,5,13). Mechanical fatigue, tissue dehydration, and decreased internal support especially in the presence of large restorations reduce tooth resistance to stress (9,13,14).

The configuration of the cusps also has an impact on stress distribution: steep inclined cuspal planes and pronounced grooves concentrate tensile forces at the marginal ridges, predisposing them to cracking (3,13). The teeth can get weaker during a removal of healthy tissue during cavity preparations or the use of excessively rigid restorative materials can alter stress transmission and lead to fracture (3). Understanding these interactions is crucial to interpret the mechanisms responsible for CTS and its clinical behavior.

1.3 Etiopathogenesis and risk factors

CTS has a multifactorial etiopathogenesis, incorporating mechanical, biological, and iatrogenic elements. Intrinsic factors include the aging process of dental tissue, which reduces the elasticity of dentin and increases its vulnerability. Teeth with high cuspal inclination or deep occlusal grooves are more susceptible to fracture because they accumulate occlusal stress (3,6,13). In some cases deep overbite, Class II malocclusion has been reported to be a risk factor (3). Extrinsic factors refer to successive occlusal trauma such as bruxism, teeth clenching, or consumption of hard foods (nuts, bones, ice cubes, etc.).

Parafunctional habits such as onychophagia, thermal changes from alternating hot and cold foods, and asymmetric mastication also accelerate microcrack propagation (2,13).

From an iatrogenic perspective, particularly MOD restorations, they reduce the amount of internal dentin and compromise the integrity of the tooth structure. Large metal restorations with a high modulus of elasticity directly transmit stress to the underlying dentin creating high pressure zones, promoting crack initiation(13,14). Many authors emphasize the crucial role of occlusal imbalance and chewing habits. Chewing on one side and premature contacts

exacerbate load asymmetry and wear on the posterior teeth (3). So high mechanical stress greatly increases the risk of tooth cracks. When a patient is missing teeth, the remaining ones must absorb more force, making them more prone to cracks(1)

1.3.1 Root canal therapy

It has been shown that root canal therapy increases the risk of cracked tooth.

Significant amount of stress is created along the root surface by the mechanical action of endodontic tools and the canal walls during the instrumentation phase, which may put the tooth at risk for fracture development. On top of that carrying out the process under dry circumstances, affects dentin integrity and increases the likelihood of fractures and consequent structural failure.(1) The use of posts and sodium hypochlorite solutions during irrigation participate in weakening the internal walls, certain obturation techniques are other operational elements that may also contribute to this process, for instance during the condensation with endodontic thermocompactor the plugger is in direct contact and at 200 degrees which might alter the structure of the walls.(1) The quantity of dentin removed and the development of CTS are significantly correlated, and excessive root canal widening can further raise the risk of vertical root fractures. It is explain by some authors that the thickness of the axial wall is an important parameter, less than 2mm per wall change drastically the prognostic. (1,2) Endodontic treatment may allow preservation of cracked teeth when the pulp is affected and the fracture does not extend into a non-restorable radicular split.(15)

1.3.2 Head and neck radiation therapy

Dental structure is significantly impacted by head and neck radiation therapy.

It affects directly the teeth by changing its internal protein and encouraging the development of more porous enamel. Moreover, HNRT might affect the salivary gland production thus reducing salivary flow. It causes the oral environment to dry up, which weakens the interphase between the dentin and enamel, it reduces fracture toughness, and dehydrates the amount of organic material at the amelodentinal junction. These changes in the properties of the amelodentinal junction also lead to a redistribution of mechanical stresses, thereby increasing the likelihood of enamel craze line (ECL) appearing in the enamel (1).

1.3.3 Bacteriology

Cracks create a sheltered space that encourages biofilm to develop along the fracture line. As saliva and debris accumulate, microorganisms and their by-products can diffuse into the dentinal tubules, or even enter them directly when the crack exposes the tubule openings. This enables bacterial components to reach the deeper layers of dentin and trigger an inflammatory response (11) whose severity depends on the depth of
infiltration. Inflammatory reactions such as reversible or irreversible pulpitis (3,12) and ultimately to necrosis. The crack serves as a pathway for microbial penetration from the oral cavity toward the pulp, which explains the rapid progression of tissue damage in cracked teeth. It is important to understand this progressive pathophysiology in order to determine the timing and nature of the appropriate intervention.(11) The spread of microcracks is facilitated by the combination of intrinsic fragility and extrinsic overload resulting in progressive crack propagation from the crown toward the root.

1.4 Diagnosis

1.4.1 Challenges and limitations

Assessing CTS remains a complicated challenge in restorative and endodontic dentistry. Symptoms are often vague, and patients find it difficult to locate the pain (7,8). In some cases the pain may increase while in others it decreases (16). The typical pain is usually sharp and short when biting or when pressure is released, often triggered by cold (usually not in early stage) (7). However, not all cracked teeth show symptoms, which makes early detection more complex. (16)
An objective visual examination need to be done where we will look for enlarged jaw muscles which can suggest heavy bruxism, craze line, cracked restorations, spaces between fillings and tooth structure, occlusal wear.(8)

The diagnostic protocol is based on a combination of clinical examinations and imaging. Commonly used methods include the selective bite test (Tooth Slooth), fiber optic transillumination, and the use of methylene blue staining to highlight the fracture (7,8). However numerous other tests exist and are being implemented over time. Thermal and electrical tests are used to assess pulp vitality, while periodontal examination helps to detect thin, isolated pockets, punctual probing is often associated with CTS (8,9)

Detection by radiography is complex, in particular, when the X-ray beam does not travel through the fracture line, fractures would be misdiagnosed (7,16). Therefore, cone beam computed tomography (CBCT) has become an essential tool for three-dimensional observation of crack propagation (17). In addition, optical coherence tomography (OCT) and artificial intelligence-assisted image analysis are recent innovations that enable early, non-invasive identification of microcracks (8). Even though numerous diagnostic methods are available for the detection of cracked teeth, no single test alone is sufficient to reliably establish the diagnosis.(18)

1.4.2 Clinical examination

Tactile examination:

Using an explorer, the dentist evaluates surface irregularities, marginal ridge defects, or catch points. Tactile feedback can indicate discontinuity along the occlusal surface. (8)

Palpation:

Digital palpation of the soft tissues around the tooth at the level of the apex which could reveal localized pain due to an apical inflammation. Does not indicate crack but secondary sign. (8)

Percussion:

Vertical and horizontal percussion help identify periodontal or periapical involvement. Angular percussion is useful because it can open the fracture line, stimulate the periodontal ligament, or force fluid into the dentinal tubules causing discomfort and help the diagnosis (8)

Wedging forces:

Applying controlled lateral pressure. This maneuver is particularly sensitive because it directly stresses the fracture line, often reproducing the patient's sharp pain. When pressure is applied to the opposite wall, a cracked tooth shows no movement between the segments. If the segments actually separate, the tooth is considered a split tooth. (8)

Bite tests:

Bite tests (Tooth Slooth) remain one of the most reliable tools in clinical diagnostics. The patient bites on different cusps or surfaces of the tooth while the device isolates specific areas. the pain appears on release more frequently than on biting. suggestive of a crack, due to rapid separation and compression of the fracture plane. (8)



Figure 2: *Tooth Slooth device*

Vitality testing:

Cold or electric pulp testing evaluates the functional state of the pulp. Vitality tests help estimate whether the pulp is reversible, irreversible, or necrotic, guiding treatment planning. (8)

Periodontal examination:

A narrow, Punctual deep probing depth is considered a sign of a vertical crack extending subgingivaly. It highlights that this probing pattern is not common but, when present, increases diagnostic confidence because it suggests the crack has followed the root surface. (8)

1.4.3 Imaging

Periapical radiographs:

This is an affordable imaging method but are not the ideal to show cracks because the fracture line usually appears parallel to the X-ray beam. However it may show secondary lesion like widening of the the PDL space, but they rarely reveal the crack itself.(7)

Cone-Beam Computed Tomography (CBCT):

CBCT offers a 3D representation of the tooth and surrounding structures. It is very useful for identifying secondary lesions and vertical root fracture, such as isolated bone loss or periapical changes. However, the resolution of CBCT is not sufficient to reliably visualize enamel or dentin cracks directly.(7) Recent studies have explored modifications of conventional CBCT imaging, such as contrast-enhanced CBCT, to improve the detection of fracture lines and crack depth.(19)

Micro-CT:

Micro-CT provides extremely high-resolution imaging. It uses a high-precision X-ray source to create detailed 3D images of teeth, with resolution far more sensitive than CBCT. It can detect early vertical root fractures and verify dentinal microcracks after endodontic treatment.

However, its ultra-high resolution comes at a cost, it produces more imaging artifacts and exposes patients to high dose of radiation. Therefore, we need to take into account risk–benefit ration with this method(7)

MRI:

MRI produces detailed images of both hard and soft tissues using non-ionizing radiofrequency waves. With specialized sequences it can visualize calcified dental tissues and detect micro-cracks as small as 20 µm. It also captures 3D images of teeth and surrounding tissues at the same time. However, despite its potential, MRI is rarely used for cracked teeth because it is expensive, complex to operate, and not widely available in dental settings.(7)

Optical coherence tomography (OCT):

OCT is a radiation-free imaging technique. It uses light to produce detailed views of the tooth's internal structure. It can detect early enamel changes, hidden cracks, and microleakages with a good resolution. Studies show it identifies vertical root fractures with over 90% accuracy and often reveals micro-cracks that X-rays or CBCT cannot see. Making OCT a promising tools for diagnosing fine dental fractures.(7)

Ultrasonography:

It is a technique that uses ultrasound, high-frequency sound waves to visualize dental tissues without radiation. Early studies showed it can measure enamel and dentin thickness and detect caries, periapical lesions, and even small cracks. However, interpreting ultrasounds in teeth is challenging because of their complex shape, and the technique requires specific expertise. This limits its routine clinical use for cracked tooth diagnosis.(7)

1.4.4 Exploratory excavation

Staining:

Dyes such as gentian violet or methylene blue can be used to make cracks lines easier to see, whether on the outer surface of the tooth, inside a cavity after removal of a restoration, or on a surgically exposed root. These inks flow into the cracks and improve visibility.(8)

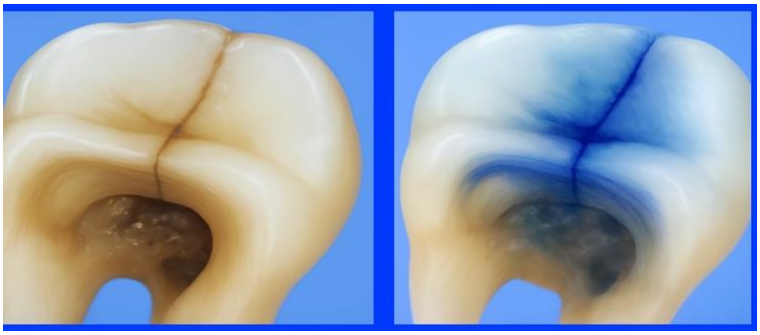


Figure 3: *Comparison between an image without dye and an image with dye using methylene blue.*

Magnification:

The use of a magnification between 14× and 18× provides the best visual assessment of enamel cracks. Moreover, it allows clinicians to take clear photos for documentation and tracking purposes.(8)

Transillumination:

Transillumination is an inexpensive and easy technique commonly used in dental clinics. It works by directing a concentrated light usually from a fiber-optic source through the tooth. Healthy tooth structure lets the light pass, while cracks block it, creating a clear contrast. This method becomes even more effective once restorations are removed and is best used together with magnification.(8)

Surgical assessment:

Surgical exploration is only used when a root fracture is strongly suspected but cannot be confirmed by other tests. These fractures become much easier to identify once the area has been surgically exposed. (8)

There are many diagnostic methods available, and new ones continue to appear, but not all of them are suitable for everyday clinical practice. Despite these advances, assessing the depth and clinical significance of a crack remains subjective and relies largely on the professional's experience. (13) Early diagnosis is essential: Structural stabilization can prevent involvement of the dental pulp and progression of the fracture. However, late diagnosis often leads to irreversible damage requiring endodontic treatment or extraction (5,13).

1.5 Treatment and prognosis

The management of cracked teeth depends on the severity of the fracture and the condition of the pulp. When the pulp is still alive, the goal of treatment is to strengthen the structure and protect the edges of the crack from stress. Indirect adhesive restorations, such as onlays, overlays, or occlusal veneers, have proven effective in distributing stress and increasing tooth durability (9,12,13).

Studies indicate that materials with a higher modulus of elasticity, such as lithium disilicate ceramic (e.max), distribute stress more effectively compared to composites or amalgams (13,14) On the other hand, metal or excessively rigid repairs can exacerbate crack progression by directly transferring stress to the dentin (14). When the pulp is affected, endodontic therapy followed by a complete cusp restoration is recommended (9). The assessment is influenced by the orientation and depth of the crack, as well as its extension below the cementoenamel junction. Long-term research indicates that, despite the apparent stability of cracked teeth under observation, nearly 20% ultimately require endodontic treatment or extraction (5,16) Current methods favor conservative management: for situations with mild symptoms and limited cracks, monitoring combined with occlusal correction can prevent worsening (3,16). The practitioner's task is to strike a balance between treatment and preservation, ensuring both mechanical strength and biological conservation.

1.6 Justification

Although there are numerous publications on the subject, cracked tooth syndrome has not yet been standardized in terms of diagnosis or treatment. The lack of consensus is highlighted by the wide disparity observed in the literature regarding prevalence, diagnostic methods, and clinical outcomes (2–4). Some practitioners rely on CBCT or OCT examinations, while others exclusively on clinical assessment. Therefore, the decision to favor a conservative or invasive method differs depending on the research (3,9,12). It is crucial to conduct a systematic literature review to summarize and examine the information already available.

This topic is also relevant in terms of prevention and clinical practice. Early identification and appropriate treatment of cracks can prevent irreversible pulp complications and tooth loss. We need to Preserve the natural tooth, which is the main goal of contemporary dentistry (5,13).

By incorporating biomechanics and diagnostic advances, healthcare professionals can Fine tune their treatment plans and optimize clinical outcomes of CTS

2 OBJECTIVE

The purpose of this review is to clarify the etiopathogenesis mechanisms, determine reliable diagnostic criteria, and assess the clinical efficacy of current treatments in order to optimize prognosis and quality of care.
Ultimately, this study seeks to answer the question:

To what extent are current diagnostic and therapeutic modalities effective in the evidence-based management of cracked tooth syndrome?

3 MATERIALS AND METHODS

3.1 Study design

Based on the methodical gathering, selection, and analysis of scientific material regarding fractured tooth syndrome (CTS), this project was done as a documentary research study. With established criteria and a research strategy, this design preserves methodological transparency while allowing a comprehensive examination of the subject.

3.2 Research question (PICO)

To provide a coherent structure to the investigation, the research question was formulated using the PICO approach:
P (Population): Patients presenting with cracked tooth syndrome.
I (Intervention): Diagnostic and therapeutic methods currently used for CTS.
C (Comparison): Alternative diagnostic or treatment strategies, or absence of intervention.
O (Outcome): Diagnostic accuracy, clinical effectiveness, and tooth preservation.

This frame-work supports the central aim of the study:
To evaluate to what extent current diagnostic and therapeutic modalities contribute to effective evidence-based management of cracked tooth syndrome.

3.3 Information sources and search strategy

The literature search was performed using major biomedical databases, primarily:
PubMed and MEDLINE. These sources were selected for their reliability and extensive coverage of peer-reviewed dental and medical publications. The search took place between January and February 2025.
A combination of terms related to CTS was used, including:
“Cracked tooth syndrome”,
“Longitudinal tooth fracture diagnosis”,
“Cracked tooth treatment”,
“CBCT cracked tooth”,
“Tooth crack biomechanics”,
“Endodontic management cracked teeth”.

3.4 Inclusion /Exclusion criteria

Articles were considered eligible when they met the following conditions:
-Publication date between 2015 and 2025
-Focused specifically on cracked tooth syndrome
-Addressed diagnostic methods, imaging modalities, etiopathogenesis, biomechanical aspects, treatment strategies, or prognosis.
-Full-text availability
-Clinical studies, observational studies, cohort studies, review papers, or finite element analysis studies with clinical relevance.

Studies were excluded if they:
-Did not focus specifically on CTS or mentioned it only partially
-Were published before 2015
-Were isolated case reports, except when providing key conceptual insights

4 RESULTS

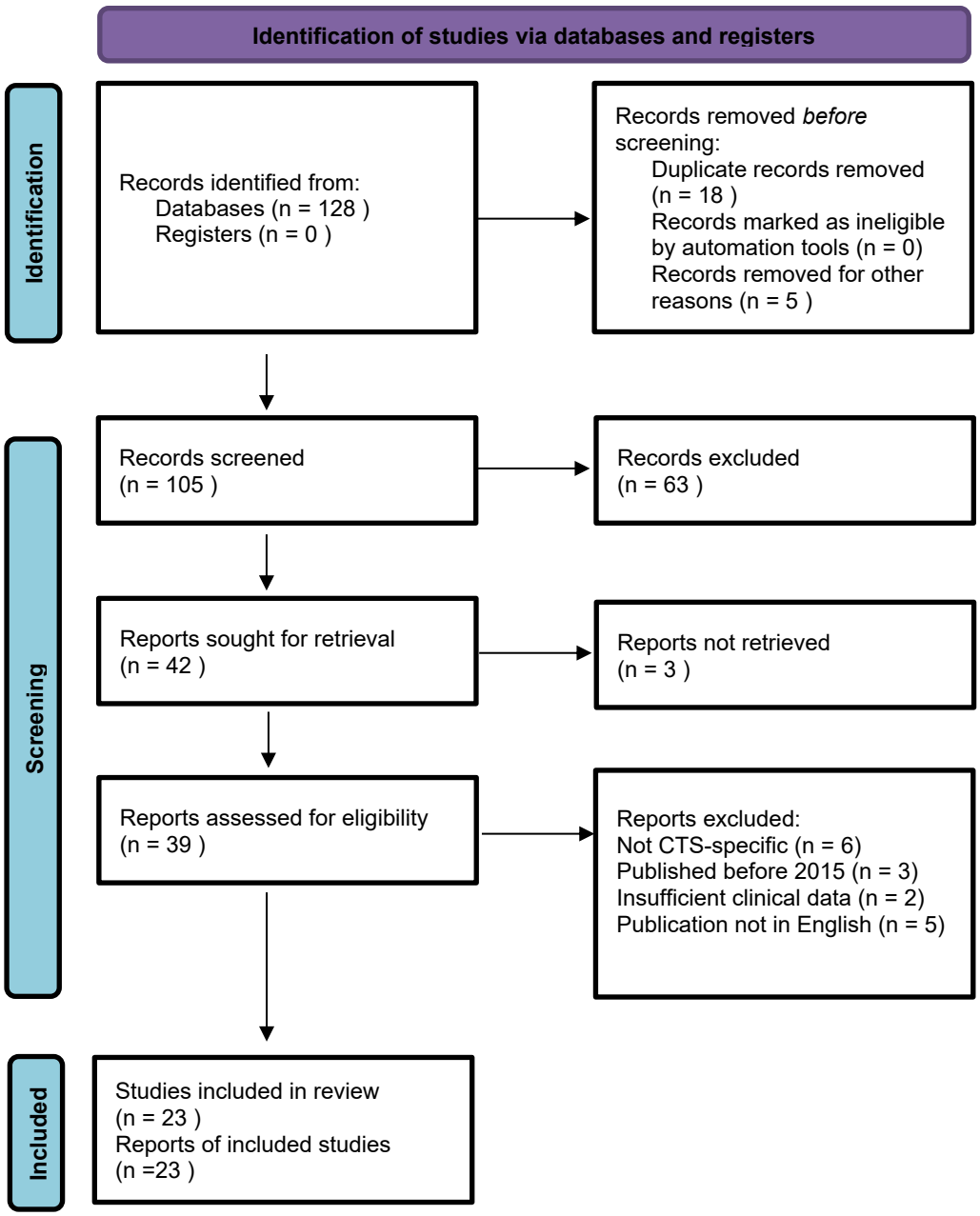


Figure 4: *Prisma 2020 Flow diagram*

(20)

The study selection process was conducted according to the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The PRISMA flow diagram illustrates the different stages of identification, screening, eligibility assessment, and inclusion of the studies considered in this review.

To improve clarity and readability, the results were divided into two separate tables. This structure allows a clear distinction between studies focusing on the diagnosis of cracked teeth and those addressing their treatment and prognosis

Table 1: *Diagnosis of cracked teeth:*

This table summarizes studies investigating the diagnostic aspects of cracked teeth

Article	Methodology	Samples	Result
Kindaro et al., 2025.	In-vitro diagnostic accuracy study comparing four visual diagnostic techniques (transillumination, macro-photography, low-magnification microscopy, high-magnification microscopy). Micro-CT served as the reference standard.	30 extracted teeth with cracks evaluated by four examiners.	- Micro-CT confirmed cracks extending beyond the dentino-enamel junction in 80% of specimens. - Transillumination showed 65.3% diagnostic accuracy and 68.8% sensitivity. - High-magnification microscopy showed 92.9% specificity and 96.7% positive predictive value (PPV). -Low-magnification microscopy showed 52.2% diagnostic accuracy. - Experienced clinicians achieved higher diagnostic accuracy 64.6% vs 56.8%(6)
Alaugaily & Azim, 2022.	Retrospective clinical study evaluating CBCT and periapical radiographs to identify bone-loss patterns associated with cracked teeth and vertical root fractures.	95 patients with longitudinal fractures, including cracked teeth and vertical root fractures; 54 had complete clinical and radiographic datasets.	- CBCT had 4.4-times higher odds of detecting bony defects suggestive of longitudinal fractures compared with periapical radiography. - Angular defects were observed in 46% of cracked teeth. - J-shaped or combined defects were detected in 92% of teeth with

			vertical root fracture. - Angular defects were significantly associated with fractures limited to the crown), whereas J-shaped defects were associated with radicular extension - Deep probing (≥6 mm) was significantly associated with radicular fracture extension - angular defects with crown-limited fractures ($p < 0.0001$) - J-shaped defects with radicular extension ($p = 0.0002$) - deep probing ≥6 mm with radicular extension ($p = 0.028$**)** (17)
Zhou et al., 2022	In-vitro experimental study comparing conventional CBCT and contrast-enhanced CBCT. Micro-CT was used as the reference standard to evaluate crack detection and depth measurement.	31 artificially cracked teeth.	- Pre-CBCT sensitivity 48.4%. Contrast-enhanced CBCT sensitivity 67.7%. -Agreement between contrast-enhanced CBCT and micro-CT ICC = 0.753 - ($p = 0.480$). (17)
Alaugaily & Azim, 2022	Sub-analysis of the retrospective clinical dataset evaluating correlation between periodontal probing depth and internal	54 patients with complete clinical and radiographic data.	- Among fractures limited to the crown: 22 teeth had probing depth **<**6 mm and 6 teeth had probing depth ≥6 mm. - Among fractures with radicular extension: 13 teeth had probing

	fracture extension using CBCT imaging.		depth <6 mm and 13 teeth had probing depth ≥6 mm. - Association between probing depth and fracture extension was statistically significant (p = 0.028). (17)
Kindaro et al., 2025.	Sub-analysis of the diagnostic accuracy study assessing the ability of each diagnostic technique to identify crack location.	30 cracked teeth evaluated by four examiners.	- Transillumination showed the highest location accuracy (54.6%), followed by DIAGNOcam (51.5%) and macro-photography (51.0%). -Lower accuracy values were observed for high-magnification microscopy (49.9%), medium magnification (44.4%), and low magnification microscopy (43.4%).(6)
Kindaro et al., 2025.	Statistical analysis of predictive values of visual diagnostic methods evaluated against micro-CT reference standard.	30 cracked teeth evaluated by four examiners.	- Positive predictive value ranged from 80.3% to 96.7% depending on the diagnostic technique used. - Negative predictive values ranged between 25.3% and 34.7%. (6)
Raj & Singh, 2025.	Review article evaluating diagnostic procedures used to identify cracked teeth including bite tests, periodontal probing, transillumination, and radiographic examination.	Compilation of previously published clinical studies evaluating cracked tooth diagnosis.	- Pain on biting and pain upon release of pressure were reported as characteristic clinical symptoms associated with cracked teeth. -Localized periodontal probing defects were frequently associated with cracks extending below the gingival margin. (8)

Guo et al., 2022.	Review describing emerging imaging techniques used for crack detection including optical coherence tomography (OCT), cone-beam computed tomography (CBCT), and ultrasound imaging.	Review of experimental and clinical imaging studies evaluating diagnostic techniques.	- Optical coherence tomography was reported to detect enamel cracks with depths of approximately 2–3 mm. - Detection of microcracks using conventional CBCT remained limited due to voxel size and spatial resolution constraints. (7)
Yap et al., 2023.	Review evaluating structural characteristics, etiology, and diagnostic difficulties associated with cracked teeth.	Compilation of clinical and experimental studies related to cracked tooth diagnosis.	-Cracked teeth frequently present with inconsistent clinical symptoms and may not be visible on conventional periapical radiographs, which may delay diagnosis.(2)
Yu et al., 2022.	Literature review summarizing clinical and imaging diagnostic methods for cracked teeth.	Review of studies investigating clinical and imaging diagnostic techniques.	- Diagnosis of cracked tooth requires combining clinical tests such as bite test, transillumination, probing and radiographic examination because no single method can reliably detect all cracks. - Conventional radiographs often fail to directly visualize cracks; diagnosis is frequently based on indirect signs such as periodontal or periapical bone changes.(18)

Lee et al., 2021	Retrospective clinical study analysing diagnostic findings, treatment procedures and prognosis of cracked teeth.	253 cracked teeth (68) from 2009 and 185 from 2019).	- Teeth with probing depth >6 mm and symptoms were significantly more likely to require root canal treatment. - Teeth with probing depth <6 mm and no apical lesion were significantly more likely to become asymptomatic during follow-up (21)

Table 2: *Treatment and prognosis of cracked teeth*

This table presents studies focusing on the management of cracked teeth and their clinical outcomes.

Article	Methodology	Samples	Result
Ferracane et al., 2022	Prospective multicenter cohort study evaluating clinical outcomes of cracked posterior teeth over a 3-year follow-up, including a sub-analysis of restorations that failed during follow-up.	478 treated teeth (out of 659 recommended for a single definitive treatment at baseline)	- 67/478 (14%) were classified as failures (need for additional treatment beyond the initial recommendation). (22)
Ferracane et al., 2022	Sub-analysis "monitoring recommended at baseline (Y0)"	1,688 teeth recommended for monitoring at baseline	- 232/1,688 (14%) were later recommended for treatment during follow-up. - 1,347/1,688 (80%) remained under monitoring recommendation throughout the entire 3-year period. (22)

Ferracane et al., 2022	Analysis of restorative materials associated with failure	Restorations placed on cracked posterior teeth that later failed during follow-up	- Composite restorations were the most common material found among failed restorations, followed by amalgam. Mean time to failure was approximately 18 months.(22)
Ferracane et al., 2022	Analysis of failures according to restoration type	Restorations classified as failures during follow-up	- Failures were recorded in 74 restorations during follow-up. Among these failed restorations, - 47 (64%) were intracoronal restorations, -24 (32%) were full crowns, - (4%) were partial coverage restorations. (22)
Kang et al., 2016	Retrospective study; Kaplan–Meier survival analysis after root canal treatment (RCT)	175 cracked teeth identified over 5 years; survival analysed for 88 teeth treated with RCT; VRF and split teeth were extracted (excluded from survival analysis)	- Two-year survival after RCT: 90.0%. (23)
Kang et al., 2016	Prognostic analysis	Same RCT cohort (n = 88); comparison according to probing depth	-Two-year survival: 96.8% when probing depth <6 mm vs 74.1% when probing depth ≥6 mm (p = 0.003)(23)

		2009: n = 68; 2019: n = 184 (distribution of treatment strategies); cracked teeth (type/extension not specified)	-Proportion "RCT + provisional restoration → crown": 52.9% (2009) vs 37.0% (2019), p = 0.032. (21)
Lee et al., 2021	Short-term clinical follow-up (3 and 6 months)	Prognosis according to probing depth at 3 months (n = 225) and 6 months (n = 79)	-At 3 months (2009 + 2019): asymptomatic ("free") 95.0% if PPD <3 mm vs 58.8% if PPD >6 mm. -At 6 months: 88.6% if PPD <3 mm vs 66.7% if PPD >6 mm. (21)
Lee et al. (2021)	Retrospective evaluation of treatment protocols applied to cracked teeth depending on pulpal diagnosis.	Cracked teeth diagnosed through bite tests, transillumination and clinical examination.	-When cracked teeth were diagnosed with irreversible pulpitis or pulp necrosis, root canal treatment was performed prior to final restoration, indicating pulpal status strongly influences treatment choice.(21)
Davis & Shariff, 2019	Prospective cohort study evaluating cracked teeth with radicular extension treated endodontically	70 cracked teeth requiring RCT and restored coronally	-Survival was 100% during the first 2 years and 96.6% up to 4 years. (15)
Zhao et al. (2024)	Prospective clinical follow-up study evaluating occlusal	27 cracked teeth in 24 patients presenting biting or cold pain	-Occlusal veneer restoration showed 92.6% success rate at follow-up. Pulp

	veneer restorations in cracked teeth using lithium disilicate ceramic.	without spontaneous pain; cracks limited to enamel and dentin.	survival rate at 12 months was 92.6%, and tooth survival rate was 100%. Pain symptoms disappeared in most teeth after treatment.(12)

5 DISCUSSION

5.1 Diagnostic performance of clinical examination methods:

The studies included in this review suggest that commonly used clinical diagnostic tests provide useful information for identifying cracked teeth, although their diagnostic performance remains variable. In one of the experimental studie conducted, micro-CT imaging confirmed cracks extending beyond the dentino-enamel junction in approximately 80% of the examined teeth (6). When different visual diagnostic methods were compared, transillumination showed a diagnostic accuracy of 65.3% and a sensitivity of 68.8%. High-magnification microscopy demonstrated higher specificity and positive predictive value, reaching 92.9% and 96.7% respectively(6). It may indicate that magnification and enhanced visualization techniques can improve crack detection under controlled conditions. However, the same study also reported differences between examiners, with experienced clinicians achieving higher diagnostic accuracy than less experienced operators (64.6% versus 56.8%)(6). It may suggest that interpretation of visual findings still depends partly on clinical experience.

Clinical examination remains an important component of the diagnostic process. Bite tests and transillumination are commonly used to reproduce symptoms or reveal discontinuities in the tooth structure. The review by Raj and Singh reports that pain during biting or upon release of pressure is frequently described as a characteristic clinical symptom of cracked teeth(8). However, these signs are not always present and may vary depending on the stage of crack propagation(8). These clinical tests are therefore generally interpreted together rather than individually.

5.2 Periodontal findings and crack extension:

Periodontal examination may also provide indirect information about the possible extension of a crack. Narrow and localized probing defects have often been described as clinical indicators suggesting that a fracture may extend toward the root surface(8).In the retrospective CBCT study (17), periodontal probing depth showed a significant association with fracture extension. Among fractures limited to the crown, 22 teeth presented probing depths lower than 6 mm, whereas 6 teeth showed probing depths greater than or equal to 6 mm(17). In contrast, fractures with radicular extension were observed in 13 teeth with probing depths lower than 6 mm and in 13 teeth with probing depths greater than or equal to 6 mm. This association between probing depth and fracture extension was statistically significant ($p = 0.028$). These

findings may suggest that periodontal probing depth could provide useful information regarding the potential extension of the crack, although the overlap observed between groups indicates that probing depth alone cannot confirm the diagnosis(17).

5.3 Radiographic findings and CBCT bone patterns

Radiographic examination is frequently used when cracked teeth are suspected, although fracture lines are rarely visible on conventional periapical radiographs(18)**.** Crack orientation often runs parallel to the X-ray beam, which means that fractures may not be directly visible. Diagnosis therefore frequently relies on indirect radiographic signs rather than direct visualization of the fracture line. Thanks to the CBCT analysis, additional information is provided regarding bone changes associated with longitudinal fractures(17). In this study, angular bone defects were observed in approximately 46% of cracked teeth, whereas J-shaped or combined bone defects were detected in 92% of teeth presenting vertical root fractures (17). It also reports that angular defects were significantly associated with fractures limited to the crown ($p < 0.0001$), whereas J-shaped defects were significantly associated with fractures extending radicularly ($p = 0.0002$). These findings may suggest that certain CBCT bone-loss patterns could help clinicians estimate the likely extension of a fracture when the crack itself cannot be clearly visualized(17).

5.4 Limitations of imaging techniques for crack detection:

Despite the advantages of three-dimensional imaging, several studies suggest that current CBCT technology remains limited for detecting small crack lines directly(19). The experimental study comparing conventional CBCT with contrast-enhanced CBCT reported that sensitivity increased from 48.4% to 67.7% when contrast enhancement was used. However, according to Zhou et al this improvement was not statistically significant when compared with micro-CT imaging used as the reference method ($p = 0.480$) (19). These results may indicate that even with improved imaging protocols, detecting fine enamel or dentinal cracks remains difficult.

Other imaging modalities have been explored in order to improve crack detection. Emerging imaging techniques such as optical coherence tomography, which has been reported to detect enamel cracks with depths of approximately 2 to 3 mm in experimental settings(7). Nevertheless, these technologies are not yet widely used in routine dental practice because of their cost, technical complexity, and limited availability. For this reason, imaging findings are

generally interpreted in combination with clinical examination rather than as definitive diagnostic evidence(7).

5.5 Diagnostic indicators and potential prognostic implications

Some of the diagnostic indicators described above may also provide information regarding the possible progression of cracked teeth(21). Teeth presenting periodontal probing depths greater than 6 mm were significantly more likely to require root canal treatment during follow-up however, teeth with probing depths lower than 6 mm and without apical lesions were more likely to become asymptomatic during follow-up (21). These findings may suggest that periodontal probing depth and radiographic findings could contribute not only to identifying cracked teeth but also to estimating their potential progression.

5.6 Diagnostic approaches in daily clinical practice

In daily clinical practice, the diagnosis of cracked teeth often relies on relatively simple clinical procedures rather than advanced imaging techniques. Bite tests, transillumination, periodontal probing, and periapical radiographs remain among the most frequently used diagnostic tools in routine dental examination(8). These methods are commonly used because they are accessible, inexpensive, and easy to perform during a standard clinical consultation. However, as emphasized by Yu et al., no single diagnostic test appears capable of reliably identifying all cracks(18). For this reason, clinicians generally combine several diagnostic tools in order to improve diagnostic confidence.

Overall, the studies included in this review suggest that the diagnosis of cracked teeth usually relies on the integration of multiple clinical and radiographic findings rather than a single definitive test (2). Clinical symptoms, visualization techniques such as transillumination, periodontal probing patterns, and imaging findings may each provide partial information regarding the presence and possible extension of a crack. However, interpretation of these findings remains dependent on clinical judgment and may require careful monitoring over time when diagnostic certainty cannot be immediately established (18).

5.7 Treatment strategies and monitoring

The studies included in this review suggest that cracked teeth may be managed through different approaches depending on symptom intensity, pulpal status, and the suspected extent

of the fracture. One of the most relevant findings comes from Ferracane et al., who reported that among 1,688 teeth initially recommended for monitoring, only 232 teeth (14%) were later recommended for treatment during follow-up, while approximately 80% remained under monitoring recommendation throughout the three-year period (24). These findings indicate that many cracked teeth remain clinically stable over time and that immediate intervention may not always be necessary when symptoms are limited and structural damage appears minimal.

Similar observations have been reported in clinical studies evaluating symptom evolution and treatment decisions(21). Teeth presenting shallower probing depths and no apical lesion were more likely to become asymptomatic during follow-up. At three months, asymptomatic status was observed in 95.0% of teeth with probing depths lower than 3 mm compared with 58.8% in teeth with probing depths greater than 6 mm. At six months, the same tendency persisted, with 88.6% of teeth with probing depths lower than 3 mm remaining asymptomatic compared with 66.7% of teeth with probing depths greater than 6 mm (21). These findings suggest that favorable periodontal conditions may increase the likelihood of successful monitoring.

In the study by Hilton et al., treatment recommendations varied according to symptoms, pulpal diagnosis, and the perceived extension of the crack. Teeth with minimal symptoms were often managed through monitoring or conservative restorations, whereas more extensive cracks or teeth presenting pulpal involvement were more frequently treated with cuspal coverage restorations or endodontic therapy. These observations highlight the importance of integrating structural and biological factors when determining the most appropriate management strategy (16).

5.8 Restorative approaches and structural stabilization

Restorative treatment appears to play an important role in stabilizing cracked teeth, although outcomes may vary according to the type of restoration placed(22). In this study 478 teeth received the definitive treatment initially recommended at baseline, and 67 of these teeth (14%) were later classified as failures because they required additional treatment beyond the original recommendation. This finding suggests that restorative stabilization can preserve function in many cases, although a proportion of teeth may still require further intervention(22).

The same study also provided information regarding the type of restorations associated with failure. Among the 74 restorations classified as failures, 47 were intracoronal restorations, 24 were full crowns, and 3 were partial coverage restorations. Composite was reported as the most common material among failed restorations, followed by amalgam, with a mean time to failure of approximately 18 months. These observations may indicate that restorations limited to the

intracoronal portion of the tooth provide less structural reinforcement than restorations that include cuspal coverage (22).

Conservative restorative approaches have also been evaluated. Lithium disilicate occlusal veneers were used to treat 27 cracked teeth with fractures limited to enamel and dentin. After a mean follow-up of 22.4 months, the success rate reached 92.6%. The same study reported a cumulative pulp survival rate of 92.6% and a tooth survival rate of 100% at 12 months, while pain symptoms disappeared in most cases after treatment (12). These findings suggest that occlusal veneer restorations may represent an effective conservative option when crack extension remains limited and pulp vitality can be maintained.

5.9 Endodontic treatment and long-term survival

When pulpal involvement is present, endodontic treatment may be required to maintain the tooth in function. In the retrospective study by Kang et al**.**, 88 cracked teeth treated with root canal therapy were analyzed, and the cumulative survival rate at two years was approximately 90% (23). This result suggests that endodontic treatment can provide satisfactory short-term outcomes in appropriately selected cases.

Additional data valuated 70 cracked teeth with radicular extension treated endodontically and restored coronally (15). In this study, survival remained 100% during the first two years and 96.6% after four years of follow-up (15). These results indicate that even teeth presenting deeper crack extension can sometimes remain functional when appropriate endodontic and restorative treatment is performed.

Treatment decisions are also influenced by pulpal diagnosis, teeth diagnosed with irreversible pulpitis or pulp necrosis were generally treated with root canal therapy prior to definitive restoration (21). The same study also reported a reduction in the proportion of cases treated with RCT sealed by crown decreasing from 52.9% in 2009 to 37.0% in 2019, which may reflect a gradual shift toward more conservative strategies when pulp vitality can be preserved(21).

5.10 Prognostic factors

Several clinical variables appear to influence the prognosis of cracked teeth. The two-year survival rate was 96.8% in teeth with probing depths lower than 6 mm compared with 74.1% in teeth with probing depths greater than or equal to 6 mm (23). These findings suggest that increased probing depth may be associated with a less favorable prognosis after root canal treatment. A similar tendency was observed in the study by Lee et al., in which deeper probing

depths and the presence of apical lesions were associated with less favorable symptom resolution during follow-up (21).

5.11 Interpretation in clinical practice

Overall, the studies included in this review indicate that the management of cracked teeth should be individualized and based on the clinical characteristics of each case. From a clinical perspective, the available evidence suggests that teeth presenting mild symptoms, preserved pulp vitality, and probing depths below 6 mm may often be managed through careful monitoring or conservative stabilization (21,22). When cracks are confined to enamel and dentin without pulpal involvement, adhesive restorations providing partial cuspal coverage, such as occlusal veneers or onlays, may represent an effective conservative treatment approach (12). In contrast, when structural weakening of the tooth is suspected, restorations providing cuspal coverage appear to offer greater mechanical stabilization than intracoronal restorations alone(22). Finally, when irreversible pulpal pathology is present, root canal treatment followed by appropriate coronal restoration may allow long-term preservation of the tooth(15,21,23). Taken together, these findings suggest that treatment planning for cracked teeth relies on the combined interpretation of crack extension, pulpal status, and periodontal conditions rather than on a single standardized therapeutic approach.

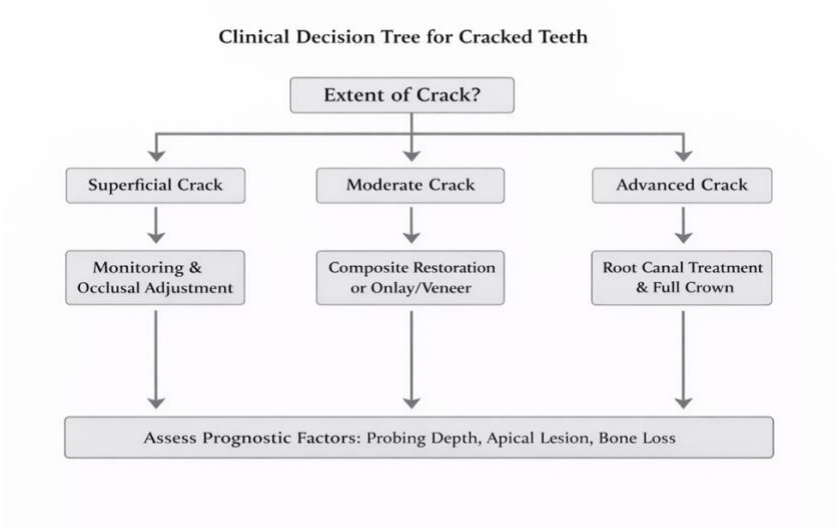


Figure 5: *Simplified Overview of clinical decision-making tree for the management of cracked teeth*

5.12 Limitations of the review

Several limitations should be considered when interpreting the findings of this review. First, many of the included studies were retrospective in design, which may introduce selection bias and limit the strength of causal interpretations. In addition, the diagnostic criteria for cracked teeth were not completely standardized across studies, which may have influenced the reported prevalence, treatment decisions, and clinical outcomes. The heterogeneity of study designs, follow-up periods, and treatment protocols also makes direct comparison between studies more difficult. Finally, most available studies report short- to medium-term outcomes, while long-term data on the survival of cracked teeth remain relatively limited. These limitations should be considered when interpreting the results and highlight the need for further prospective clinical studies with standardized diagnostic criteria and longer follow-up periods.

6 CONCLUSIONS

The findings of this review suggest that the diagnosis and management of cracked teeth remain complex and require careful clinical evaluation. Early identification is essential, as symptoms are often variable and cracks may remain undetected during routine examination. The available evidence indicates that combining several diagnostic methods, including clinical examination, bite tests, transillumination and radiographic assessment, improves the likelihood of detecting cracks and establishing an appropriate diagnosis.

The results analyzed in this review also indicate that not all cracked teeth require immediate intervention. A substantial proportion of teeth may remain stable under clinical monitoring when symptoms are limited and structural damage appears minimal. Conservative management may therefore represent a valid initial approach in selected cases.

When restorative treatment is indicated, the literature suggests that restorations providing cuspal coverage may offer better structural stabilization than intracoronal restorations alone. In cases where pulpal involvement is present, endodontic treatment combined with appropriate coronal restoration may allow the tooth to remain functional with satisfactory survival rates.

Overall, the prognosis of cracked teeth appears to depend on several factors, including crack extension, pulpal status and periodontal conditions such as probing depth. These findings highlight the importance of individualized treatment planning and careful clinical monitoring. Further prospective studies with standardized diagnostic criteria and longer follow-up periods would be valuable to better understand the long-term outcomes of cracked teeth and to refine clinical management strategies.

7 SUSTAINABILITY

Sustainability has become an important consideration in modern dental practice, particularly in relation to the preservation of natural tooth structure and the reduction of unnecessary invasive procedures. The findings of this review suggest that many cracked teeth can remain stable under careful clinical monitoring, highlighting the importance of conservative decision-making. Avoiding unnecessary extractions and overly aggressive restorative procedures contributes to the long-term preservation of natural dentition, which represents a key aspect of sustainable oral healthcare.

From an environmental perspective, conservative treatment approaches may also reduce the consumption of dental materials and clinical resources associated with complex restorative or surgical procedures. Maintaining teeth through minimally invasive treatments can therefore contribute to reducing the ecological footprint of dental care.

In addition, promoting accurate diagnosis and individualized treatment planning supports a more efficient use of healthcare resources while improving patient outcomes. By prioritizing prevention, early detection, and conservative management whenever possible, clinicians can contribute to a more sustainable dental practice that aligns with broader public health and environmental objectives.

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