Title: Prevalence and distribution of cracked tooth: a systematic review

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Abstract

A cracked tooth is an incomplete fracture initiated from the crown and extends cervical and is usually directed mesiodistally. The consequences of fracture range from minor complications requiring no treatment to severe consequences that may lead to tooth loss. Routine clinical examinations often uncover visible fracture lines in asymptomatic teeth. However, diagnosis of a cracked tooth often represents a problem. The present review aimed at assessing the prevalence and distribution of cracked teeth by reviewing previous studies investigating such subjects. PubMed and Google Scholar databases were searched for eligible articles between 2009 and 2021. The included searching keywords were "Prevalence, Distribution, Epidemiology, CTS, and Cracked tooth", which were used in various combinations. The inclusion criteria were original articles written in English and available for full-text. A total of 85 articles were obtained. Only six articles were eligible for the inclusion criteria. The six included studies involved a total number of 5055 participants. The most affected teeth were molars, and the associated risk factors were older age and male gender. The risk behaviour was biting of hard object. The prevalence of cracked teeth is hard to be determined due to the lack of studies and diversity of the included population. However, molars were found to be the most affected teeth, and older age, as well as male gender, was found to be the risk factors for cracked teeth.

Keywords: Cracked tooth, distribution, prevalence.

1. Introduction:
A cracked tooth is a tooth containing partial or complete fracture of a stress plane that commonly occurs in that tooth [1]. A tooth stress plane results from the occlusal force commonly pressed on teeth during mastication. Therefore, any instance of higher energy is concentrated along the stress planes. The higher energy, in turn, lead to the disruption of some chemical bonds within the natural tooth while transferring along the stress planes [2]. The consequences and severity of fracture range from a minor complication that requires no treatment to severe consequence resulting in root canal therapy (RCT) or even tooth loss [3].

Cracked tooth syndrome (CTS) is one form of tooth fracture [3], and it was first defined and introduced in 1964 by Cameron [4]. CTS is a term that illustrates a condition in which there is incomplete tooth fracture that typically presents with consistent symptoms of pain to biting and temperature stimuli, especially cold[3]. During biting, the pain symptoms increase as the applied occlusal force are raised [5]. Other symptoms include rebound pain which occurs on pressure release when fibrous foods are eaten [6]. Pain can also be evoked by sugar consumption in the eaten substances [7].Routine clinical examinations often uncover visible fracture lines in asymptomatic teeth [3]. The diagnosis of CTS often represents a problem. It has been a challenge even for the most experienced dental operators. This returns to the fact that the associated symptoms tend to be very variable and, at times, bizarre [8].

The studies conducted on epidemiology of the incidence of CTS are conflicting [9,10]; however, CTS is a condition that generally affects the adult population's teeth, especially those in the age range of 30-60 years old [8]. It was reported that tooth fractures are a significant cause of tooth loss in industrialized countries [11]. However, there was not enough data available on the incidence of CTS [8]. Therefore, we conducted this systematic analysis to assess and investigate the prevalence and distribution of CTS by reviewing the previous studies concerned with that subject and met our inclusion criteria.

2. Method and search strategy:

This systematic analysis follows the PRISMA checklist guidance for systematic review and meta-analysis [12]. The search process for studies conducted on the current subject included the years between 2009 and 2021 by searching through PubMed and Google scholar databases. The searching process involved using several
keywords such as "Prevalence, Distribution, Epidemiology, CTS, and Cracked tooth". The keywords were used in various combinations to obtain all possible articles due to a lack of studies. All the obtained titles from this primary exploration were revised.

1. Eligibility criteria:

After revising the obtained articles, all articles published before 2009 were excluded. The remaining articles were then explored and examined to choose only articles written in the English language and available for full-text. Therefore, the included articles were published between 2009 and 2021, written in English and available for full text. The next step involved further exclusion and inclusion of articles focusing on our current subject. The abstracts of the articles were revised to select only original articles for the final analysis and exclude duplicate articles, review articles, case reports, letters to the editor, articles with unsatisfying content such as overlapped or incomplete data. So, the eligible articles for the final analysis were original articles available for full-text written in English with precise data. The full description of the search strategy is shown in figure 1.
3. Data review and collection:

The first stage in data reviewing involved reviewing the full abstract of each study, then exploring the entire article to extract data of interest and information of concern. The data and information were extracted in a specially designed excel sheet. Then the data was revised through the excel sheet. The chosen data was then transferred in a pre-designed table to summarize and facilitate data analysis as the collected data was written under specific titles in the table.

4. Results:

This systematic review included six articles that met the eligible criteria [13-18] (Table1). Most of the studies were recently published, where two articles were
published in 2021 [13, 14], one article was published in 2020 [15], and one article was published in 2017 [16], whereas the remaining two studies were published before that; one was published in 2014 [17], and one was published in 2009 [18]. There were only two studies that reported the study design [14, 15]; one was retrospective [14], and the other was cross-sectional [15], whereas the remaining four studies did not state the study design [13, 16-18]. The total number of participants in the included studies was 5055 participants. The age range of included population was 12 years [17] to 89 years [13].

One study reported that among 65 patients, there were a total of 77 cracked teeth [13]. The remaining five studies reported heterogeneous rates of cracked teeth prevalence; one study reported the prevalence of symptoms of cracked teeth, and it was 41% [14], another study reported that the prevalence of cracked teeth among 152 patients was 9.1%; the study also reported cracked teeth prevalence and patient prevalence and they were 0.4% and 4.5%, respectively [15]. Another study included 182 patients with 182 cracked teeth representing 100% prevalence [16]. Another study reported a high prevalence of cracked teeth; it was reported that 97% of 200 patients had at least one cracked tooth and out of 5096 teeth investigated there were 37.9% of teeth had either craze or cracked lines or both [17]. The previous study reported that 8.9% of 370 patients had CTS [18].

The factors associated with CTS were reported in five studies [13-16, 18]; age older than 40 years was associated with cracked teeth [13, 14, 15, 16, 18], male gender [15] with rates of 49% [14] and 55.8% [18], Caucasian (58.9%), and African American (21.1%) populations [14], skilled (56.6%) and those attained tertiary education (77.6%) [15], and amalgam restored teeth (82%) [18].

The most affected teeth with CTS were reported in all the six studies; one study reported that the most affected teeth with cracking were molars (79.22%), non-terminal teeth in the arch (62.34%) and non-endodontically-treated teeth (94.81%) [13]. Another two studies reported that first and second molars had the highest probability for fractures (59.8%) [14], and mandibular first molar was the most frequently cracked teeth [15]. Another study revealed that cracks occurred mainly in molar teeth; mandibular second molars (25.3%), mandibular first molars (22.5%), maxillary first molar (22%) and maxillary second molar (17.6%) and were commonly
found in intact teeth with no restoration [16]. One study reported that cracked teeth were generally on both arches were first permanent molars [17], cracked molars were found among 63.6% and cracking in maxillary arch represented 51.5%[18].

Five studies reported characteristics and additional information about cracked teeth [13, 15-18]; one study reported that cracked teeth result in pain to percussion (63.64%), orbiting (74.03%), and positive mobility (76.62%)[13] and cracks were most often oriented in the mesiodistal direction (68.83%)[13]. In contrast, one study showed that cracks are centrally placed (91.7%) and run in a mesiodistal direction (61%) [15]. One study showed cracks mainly occurred in non-bonded restoration such as gold (26.9%) and were usually found in intact teeth (37.9%). Also, cracked teeth (18.1%) were diagnosed with pulp necrosis, irreversible pulpitis (22%), and with reversible pulpitis (53.3%) [16]. Only one study revealed that accidentally biting complex objects was the risk behaviour for cracking [17]. The previous study showed that all cases with cracked teeth had a positive response to the bite test and a normal response to the electric pulp test; only 10% had a positive history of the masticatory accident [18].

One study reported the diagnosis of cracked teeth, and it was reported that transillumination detected more cracked teeth (44.7%), and it was the most useful diagnostic tool[15]. Only one study reported the survival rates of a cracked tooth. It was reported that higher survival rates were noted in cracked teeth lacking preoperative pain to palpation or spontaneous pain with no positive mobility at 6-months and one year recalls[13].

5. Discussion:

A cracked tooth is an incomplete fracture initiated from the crown and extends cervical and sometimes gingival and usually directed mesiodistally [19]. In our analysis, more than one-half of cases showed that cracks oriented in mesiodistal direction (68.83%) [13] and (61%)[15]. The prevalence of CTS is lacking; one study reported that the incidence of CTS was 9.7% among 8175 patients in a period over six years [20]. In our analysis, there was heterogenicity in the prevalence rate as studies included geriatric and adolescent populations, the study design was not reported in most of the included studies, and a few studies reported the prevalence. However, the prevalence of CTS was commonly prevalent, especially among patients older than 40
years old and male patients. These two factors were the significant risk factors for a cracked tooth.

One study reported that the leading cause of cracks was malocclusion [21], whereas, in our analysis, accidental biting of complex objects was the risk behaviour of cracking [17].

It was reported that mandibular molars are the most commonly fractured teeth [22-25]; molars constitute more than 75% of cases, whereas premolars constitute the rest percentage [21], and this may return to the pointy protruding maxillary molar palatal cusps [26] occluding powerfully into the mandibular molar central grooves [1]. These findings agreed with our analysis, where molars were the most affected teeth with cracking (79.22%) [13]. Another study in our analysis also showed that mandibular first molar was the most frequently affected teeth [15]. Mandibular second and first molars represented (47.8%) of cracked teeth [16].

The pain of cracked teeth is not uniquely associated with cracked teeth, but it occurs with other causes of tooth pain such as pulpal pathology, caries or periodontal disease. The presence of percussion sensitivity indicates that the tooth has an abscess or irreversible pulpitis, which may be associated with a crack [1]. The spread of cracks leads to irreversible pulpitis; once the crack has spread and exposed the pulp, it is more predisposed to necrose and produce a periapical lesion [16]. Our analysis found that cracked teeth were diagnosed with pulp necrosis and irreversible pulpitis; however, reversible pulpitis was more common than irreversible pulpitis (53.3%. Vs 22%, respectively) [17].

Cracks of the tooth may not show up on radiographs as X-ray photons pass through a radiolucent fracture plane [1]. Cracked teeth are diagnosed through visual observation, usually using microscopes [27-29]. The dentist diagnoses a crack by observing a crack line, a line segment from the perimeter of a fracture plane located on a tooth surface that a dentist can observe [1]. Cracked tooth syndrome is a challenge for dentists at the time of diagnosis and treatment [21]. In our analysis, transillumination was the most useful diagnostic tool for detecting more cracked teeth; however, only one study diagnosed cracked teeth [15]. Also, only one study reported data on the survival rates of a cracked tooth. It was found that higher survival
rates were noted in cracked teeth lacking preoperative pain to palpation, or spontaneous pain with no positive mobility [13].

6. Conclusion:

A cracked tooth is prevalent even in patients with younger age and could be found among the population aged 12 years old. However, the exact prevalence rate is hard to determine as there are no studies conducted on such subjects. Each study involved different populations; some included adolescents and geriatric populations, and others included adult and geriatric populations. There was heterogeneity in the studies regarding the population under the studying. However, the risk factors for cracked teeth showed more explicit evidence, and they included older age than 40 years and male gender. The most affected teeth were molars. Further studies are highly recommended on this subject.

List of Abbreviations:

CTS Cracked tooth syndrome

Conflict of interest:

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Table 1: List of Studies
<table>
<thead>
<tr>
<th>Author and Publication year</th>
<th>Study design</th>
<th>Sample size and Age of participants</th>
<th>Results and main findings</th>
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| Liao et al 2021 [13]        | ------       | -65 patients                       | *77 Cracked teeth were included  
*Most cracked teeth occurred in patients greater than 40 years old  
*Cracked teeth themselves were most often molars (79.22%), a non-terminal tooth in the arch (62.34%) and nonendodontically-treated teeth (94.81%).  
*Cracked teeth exhibited pain to percussion (63.64%) or biting (74.03%), and no or only positive mobility (76.62%).  
*Cracks were most often oriented in the mesiodistal direction (68.83%).  
*Higher survival rates were noted in cracked teeth lacking pre-operative pain to palpation or spontaneous pain, and with no or only positive mobility at 6-month and 1-year recalls.  
*In vital cracked teeth, higher survival rates were noted in teeth lacking pre-operative pain to palpation and with no or only positive mobility at 2-year recalls.  
*The absence of pre-operative palpation discomfort, spontaneous pain and minimal mobility, as well as the presence of pulp vitality were associated with higher survival rates of cracked teeth at all recall times. |
| Ozuna et al 2021 [14]       | Retrospective | -893 patients                      | * 41% had documented symptoms of cracked teeth  
* Patients in the 45-54 age range had the highest number of teeth with cracks (P<0.001). |
<table>
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<tr>
<th>Study</th>
<th>Design</th>
<th>Sample Size</th>
<th>Characteristics</th>
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* Males comprised 49% of the cases.
* Caucasians (58.9%) and African Americans (21.1%) represented a majority of the population with cracked teeth (P<0.0001).
* 1st and 2nd molars had the highest predilection for fractures (59.8%).
* Mandibular and maxillary first and second molars were amongst the highest teeth affected with cracks.

*264 out of 64370 posterior teeth were cracked in 152 patients; patient prevalence was 4.5% and teeth prevalence was 0.4%.
* Amongst the 152 patients, the prevalence was 9.1%.
* There was a slightly higher male preponderance while cracked tooth was observed to increase with age (p = 0.007).
* The skilled (56.6%) and those that attained tertiary education (77.6%, p = 0.023) had more cracked teeth.
* Mandibular first molar (19.7%) was the most frequently cracked tooth type.
* The cracks were usually centrally placed (91.7%) and run in a mesiodistal direction (61%).
* Transillumination (44.7%) detected more cracked teeth.
* Prevalence of cracked tooth was observed to be low with a slightly higher proportion in male and the figure increases with age. Mandibular first molar was the most frequently cracked tooth while transillumination was the most useful diagnostic tool. Most cracks ran in the mesiodistal direction and fracture lines were usually centrally placed.
Yang et al 2017 [16]  
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-182 patients  
-Age:20-79 years  
*There were 182 cracked teeth (100%)*  
*Patients with cracked teeth were most frequently aged 50–59 years*  
*Mandibular second molars (25.3%) were the most frequently involved teeth, followed by mandibular first molars (22.5%), maxillary first molars (22.0%), and maxillary second molars (17.6%).*  
*Cracks occurred mainly in nonbonded restorations, such as gold (26.9%), and were usually found in intact teeth (37.9%).*  
*A total of 103 teeth (56.6%) had an initial PPD of less than 3 mm, while 40 (22.0%) had a PPD of 4–6 mm, and 39 (21.4%) had PPD of 7 mm or more.*  
*A total of 33 cracked teeth (18.1%) were diagnosed with pulp necrosis, 40 (22.0%) with irreversible pulpitis, and 97 (53.3%) with reversible pulpitis.*  
*The incidence of pulp necrosis was 31.8% among cracked teeth with a PPD of 4–6 mm, and 28.6% among those with a PPD of 7 mm or more.*  
*Cracks occurred mainly in molar teeth, and were commonly found in intact teeth with no restoration.*  
*Cracked teeth showing a PPD of more than 4 mm were more likely to show pulp necrosis.*  

Khovidhunkit & Songmanee 2014 [17]  
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-200 patients  
-Age:12-80 years  
*194 (97%) patients had at least one cracked tooth*  
*out of 5,096 teeth investigated, 1,932 (37.9%) teeth had either craze or cracked line(s) or both.*  
*The most common cracked teeth found on both arches were first
permanent molars
*The most common associated risk behavior was accidental biting of hard objects.
*There was a high prevalence of at least one cracked tooth in a group of patients

| Study: Udoye et al 2009 [18] | -370 patients with cracked tooth syndrome | -8.9% of patients had cracked tooth syndrome
| Age: 18-77 years | -Cracked tooth syndrome was seen most often in the 41 to 50 years age band (36.4%), in molars (63.6%), and in the maxillary arch (51.5%).
| | -Cracked tooth syndrome was more frequent in men (55.8%).
| | -About 82% of cracked tooth syndrome occurred in amalgam restored teeth.
| | -All cases had a positive response to the bite test and a normal response to the electric pulp test
| | -Only 10% gave a positive history of masticatory accident as against none with history of bruxism habits.
| | -Patients with unexplained pain in a vital, amalgam-restored tooth (especially in maxillary molars), with or without a history of a masticatory accident, may have a cracked or fractured tooth.

PPD: periodontal probing depth