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Review Article

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All About Crack Tooth Syndrome and Role of Medical Imaging in Diagnosing It: A Review

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Abstract

Dental hard tissue disease known as "crack tooth syndrome" is frequent. The presence of cracks directly impacts the preferred treatment and restoration for the afflicted teeth. To ascertain the precise involvement of the crack, choosing better treatment options and accurately determining the tooth's prognosis are both beneficial. However, it is frequently challenging to determine the extent of cracks precisely and quantitatively currently. To identify cracks early, quantitatively, and without causing damage, a workable method is needed. Traditional clinical treatments and medical imaging techniques have all been used in the diagnosis of broken teeth. A summary of various medical imaging technologies is provided in this review article.

Keywords

Crack tooth syndrome, Medical imaging, Vertical root fracture, Endodontists

Introduction

The condition known as "cracked tooth syndrome" or "split tooth syndrome" occurs when a tooth has only partially cracked but has not yet totally broken off. It is often referred to as a Greenstick Fracture. In 1964, Cameron coined the term "cracked tooth syndrome", first referring to it as the incomplete fracture of the anterior molar [1]. The American Association of Endodontists then developed a new, more thorough classification of fractured teeth based on four key characteristics: the cause of the crack, its development, the clinical symptoms, and the pulpal activity [2-5]. According to the American Association of Endodontists' guidelines, broken teeth are classified as follows: (1) Craze lines; the fracture only affects the enamel and is apparent. (2) A fractured cusp with a crack that starts in the crown, travels through the dentin, and ends at the cervical area. (3) A cracked tooth with the crack running in the occlusal to apical direction. (4) Split tooth, a crack that runs all through the mesial and distal directions of the tooth and reaches its marginal ridge. (5) Vertical root fracture [2].

Causes

The use of high-speed handpieces during cavity preparation and high occlusal forces are two major iatrogenic causes of cracked teeth [6]. The chewing of hard foods like popcorn, habits like chewing on gum or ice, large dental restorations or roots canals that weaken the tooth, clenching or grinding of teeth (bruxism), aging trauma like falls, sports-related injuries, bike collisions, automobile crashes, or assault are all possible causes of crack tooth syndrome.

The Most Probable Teeth to Crack

Although anyone can crack a tooth, young kids and the elderly are more

prone to fractures. The mandibular molars and upper front teeth are the teeth most susceptible to fractures. The most frequently impacted teeth are the lower second molars, lower first molars, and upper bicuspids. Although people often break one tooth, a more serious trauma may break many teeth. Even with less severe impact, teeth with tooth decay are more likely to crack.

Symptoms

The wide range of symptoms make it a generally difficult condition for doctors to identify. The signs and symptoms could include a "sharp pain" when biting on a particular tooth, which could get more severe if the applied biting force is increased, or a "Rebound pain," which is a sharp, short-lived pain occurring when the biting force is released. Patients may also express pain when consuming sugary foods or liquids, not having pain when exposed to heat, and acute pain when consuming cold drinks or foods. Small and unharmful cracks can occasionally occur; in other instances, it can result in tooth cracking or splitting. If the fracture spreads into the pulp, periapical periodontitis, pulpal necrosis, and irreversible pulpitis may all develop, along with their corresponding symptoms. Occasionally, when the pain is clearly localized, the person can pinpoint which specific tooth is to blame, although this is not always the case. Swelling surrounding the tooth is another frequent condition.

Diagnosis

Dental professionals have had difficulty with diagnosing the crack tooth syndrome, which can be disappointing for both the dental professional and the patient. Diagnosis is often challenging due to the possibility that the pain could be caused by another pathology, for instance sinusitis, temporomandibular joint problems, headaches and migraines, or atypical orofacial pain. Early detection of cracked teeth is crucial to prevent the fracture from spreading, cause future microleakage that involves the pulpal or periodontal structures, or cause the cusp to break irreparably.

Conventional Diagnostic Methods

Clinically, it is common to combine the patient's medical history with the results of auxiliary examinations to make the diagnosis of a cracked tooth.

Dental history/symptoms

History given by the patient about possible causes of fracture and the symptoms. Presently, the primary basis for diagnosing broken teeth is patient's clinical signs and symptoms [7].

Clinical exam

Sometimes the cracks can be visible to the naked eye. Vertical cracks could cause irritation to the gums, therefore in addition to looking for crack lines, signs of gingival inflammation should also be checked.

Bite test

Orange wood sticks, cotton rolls, Berlew wheels, a number 10 round bur head, can all be used for bite testing [8]. The patient is asked to bite on each cusp separately when the wooden sticks are used to identify the cracks on molars or premolars so that it can be determined which cusp has the crack line. Another good method of detecting a cracked tooth syndrome is by asking the patient to bit hard of cotton roll and then release abruptly, if the patient experiences pain on the release of pressure, it is almost always characteristic of a cracked tooth. Alternatively, the rubber plungers of anesthetic cartridges can be tied to floss and used for crack detection. Fractfinder (Denbur, Oak Brook, IL, USA) and Tooth Slooth II (Professional Results Inc., Laguna Niguel, CA, USA) are two other commercially accessible products that have been found to give better results in diagnosing cracked teeth. The main drawback of using bite tests in diagnosing crack teeth is that it can make the cracks worse and even lead to splitting of tooth [9].

Vitality tests

In most cases, the cracked teeth pulp responds normal and vital to the vitality test. But in some instances, the pulp can be inflamed that could cause pain with cold stimulation, in which case a root canal is indicated as per Kim et al. [10].

Transillumination

This method uses fiberoptic light and is the most widely used method which can detect both an incomplete and a complete fracture. After thoroughly cleaning the suspected tooth, when the transillumination light is positioned directly on a cracked tooth, the light transmission is interrupted. Using transillumination under magnification provides better results so the minute and delicate cracks would not go unnoticed. Main drawback of this method is inability to determine the small hidden cracks especially their type and extension of their depth into the tooth [11]. Regardless, this method is reliable in the crack tooth syndrome diagnosis and very easy to use for the clinicians in their practice.

Staining dye

Dyes like methylene blue, and Gentian violet have been used historically to detect the crack/craze lines. The drawback of staining dues is the inconvenience due to need of microscope and being a time-consuming method that can't be conveniently used in a dental office by the clinicians [12]. Another disadvantage is that the stains can only show that there is a crack, but they cannot provide information about how deep the fracture is extending into the tooth [13, 14].

Tactile exam and periodontal probing

A periodontal probe can be used sometimes to detect the crack because the tip of the probe would get stuck in the fracture line, which is usually painful [15].

Radiographic

Conventional dental x-rays would demonstrate the bone loss associated with a cracked tooth.

Various Imagining Options for the Diagnosis of Cracked Tooth

Oral X-ray radiograph

X-ray-based radiographs allow for the visualization of various tissue components according to the various levels of ray absorption [16]. In the past, an oral X-ray radiograph was frequently used to ascertain whether periapical illness was present. It might offer in-depth information about the oral cavity and help dentists find tooth cracks [17]. Both the conventional as well as the digital X-rays have been equally helpful in detecting cracked teeth. Using a long cone paralleling technique has been found to provide more clarity, and resolution of the images and hence more beneficial in the crack tooth syndrome diagnosis as compared to using a bisecting angle technique mainly because the X-ray beam needs to pass through the crack line for it to be captured by the X-rays [18, 19]. Nevertheless, incorrect diagnoses may still occur in a non-displaced fracture since anatomic features are superimposed upon indicators of diagnostic significance [20]. Vertical root fractures are especially difficult to diagnose using X-rays as they are two dimensional (2D) [21-23]. The buccolingual orientation of the longitudinal cracks may cause the nearby tissues to substantially perturb the beam, which could reduce the detection's image resolution [24]. Furthermore, the 2D images generated by oral radiography were hardly ever able to convey information on the direction or trajectory of fracture [25, 26]. Considering all these limitations of 2D radiography, it is safe to assume that a three-dimensional (3D) picture would provide better resolution and detection of even the minute cracks.

Cone-beam computed tomography

This method combines the concepts of segmented transmission of X-ray radiation, cross sectional scans, and a subsequent 3D reconstruction of the images. Computed tomography (CT) scan method originated in medical field but considering their massive equipment and the amount of space they took in the hospitals, CBCT (Cone-beam computed tomography) was developed for dental use which is much less space consuming and hence better suited for dental clinics. Many dental clinicians now use CBCT in their practices, especially oral and maxillofacial surgeons. Youssefzadeh et al. in their research found that the detection of vertical root fractures was much easier and more accurate with CBCT as compared to using the conventional 2D radiographic techniques [27]. The disadvantages of using CBCT include a higher amount of radiation exposure, the volume of the apparatus, poor resolution in space, and a higher price [28, 29].

The most popular scanning method now employed in dental offices, CBCT lessens radiation dose by locally circumferentially projecting around the mouth [30-32]. The 3D scanning method is not only superior in the resolution quality of the images but also significantly lowers the interference that might be caused by the titanium dental implants to the images. When compared to conventional oral X-rays, CBCT radiographic technique gives a 3D reconstruction of the tissues and a relatively good accuracy, particularly for detecting vertical root fractures and periapical lesions [33-36]. A study by Lin et al. found that CBCT can view anatomy of teeth, internal shape of the root canals, and periodontal structures all at the same time [37]. Research by Kalyan et al. revealed the important details about the cracks in cracked teeth including the position, orientation, and proximity of the crack to the tooth's pulp [38].

A CBCT device's resolution describes its capacity to display fine details. Voxel has a linear relationship with picture resolution [39]. The voxel size of dental CBCT scanners is frequently more than or equal tp125 microns, but sometimes can go as low as 75 microns.

These days CBCT scans are routinely used by dentists in their offices, however the issues of noise and interference still exist and can't be avoided [40, 41]. Furthermore, low resolution may mask microcracks, particularly if they are minute and in the initial phases of development [42, 43]. To resolve this problem, some researchers have found that performing a CBCT scan with use of a contrast medium and under vacuum could help with identification of the cracks which could be masked otherwise; and the issue of depth detection still remains even with contrast technique [44].

Micro-computed tomography

By circumferentially illuminating the sample with a microfocus X-ray source, 3D imaging of the tooth structure is made possible by micro-CT technology. In comparison to CBCT, the micro-CT system's high-resolution detectors and microfocus spot X-ray sources can reach a higher sensitivity. By modifying the scanning parameters, micro-CT's resolution could be increased to up to 9 m, which made it possible to diagnose vertical root fractures early on [45, 46].

Micro-CT scan can precisely differentiate between enamel and dentine of teeth, and additionally has enough resolution to visualize the width of cracks ranging from very narrow to as wide as tens of microns [47, 48]. In addition, the fracture of apices after root canal treatment is best identified with micro-CT.

But as with any other imaging modality, micro-CT has some problems as follows. Firstly, the artifacts could lower image quality. Secondly, the radiation exposure is extremely high (up to 1500mGy) as compared to conventional CBCT (1 - 70mGy). These issues need to be kept in mind when deciding whether it would be beneficial to use a micro-CT or something else [49].

Other potential techniques

These additional potential imaging modalities as described below have been developed due to their non-radiative characteristics.

Ultrasound

Ultrasound is a mechanical vibration wave with a frequency greater than 20 kHz, which is beyond the human hearing threshold [50]. The research on the detection of dental hard tissue by ultrasound was begun in the 1960's by Lee et al. [51]. The enamel and dentin thickness has been studied with ultrasound method again and again ever since [52, 53].

Culjat et al. performed research where they cracked some isolated teeth in a laboratory and used ultrasound to detect those cracks. The cracks initiated by them were up to 25 m

wide. They found that ultrasound was able to differentiate between cracked and non-cracked teeth [54]. Research by Singh et al. [55] using ultrasonic imaging equipment to examine the capacity to find cracks in gold, amalgam, and porcelain restorations revealed that gold fillings may affect how accurately ultrasound imaging works.

Furthermore, by combining the ideas of ultrasonic vibration and infrared imaging, vibrothermography (VibroIR), also known as ultrasonic vibration infrared thermography, was developed to detect cracks using the frictional heat generated by ultrasonic vibrations. The research by Matsushita et al. [56] suggested that VibroIR might detect concealed fissures in tooth tissues with a range of 4 to 35.5 m. Recent reports suggest that dual contrast photoacoustic tomography with ultrasound is employed for the early identification of dental diseases, suggesting a sufficient degree of spatial resolution and optic contrasts for tissue depth imaging [57].

In vitro cracked tooth model's complex geometry and unclear ultrasound mechanism may hinder analyzing ultrasonic imaging signals due to its acoustic properties resembling natural tooth enamel and dentin. The practicality of the procedure is further diminished by the possibility that it will require specific competence in ultrasonic inspection to identify an oral broken tooth. This may be the reason there isn't more information in the literature about using ultrasonic technology to make a more thorough assessment of cracked teeth.

Optical coherence tomography

Optical coherence tomography (OCT), a safe and non-invasive, high-resolution, radiation-free optical imaging technology, was initially developed by Huang et al. [58]. The use of OCT in applications in biology has increased recently. Through the disruption of the weak coherent light, OCT may provide 2D or 3D pictures of living tissues by identifying reverse reflection or numerous scattering signals generated by incident coherent light concentrating on various depths of the living tissues. OCT is presently employed as an additional diagnostic technique for dentinal fracture after root canal treatment, demineralization of enamel, incipient caries, and microleakage around composite restorations [59].

The resolution of OCT for crack detection is similar to micro-CT (up to 10 microns). According to a study, OCT had a substantially higher (more than 90%) sensitivity and specificity for detecting vertical root fractures [60].

The development of high-speed swept-frequency sources of light has also enabled the development of swept-source optical coherence tomography with an axial resolution of 5.3 m and an axial scan that can perform 100,000 scans per second [61]. Sensitivity and specificity have been found to be greater in OCT as compared to micro-CT [62-64].

Magnetic resonance imaging

Another important safe and non-invasive healthcare diagnosis method is magnetic resonance imaging (MRI), which uses non-ionizing radiofrequency electromagnetic radiation to produce excellent cross-sectional views of the highly calcified tissues in the body. Still, the oral hard tissue's poor hydrogen density, reduced ability to hold onto water, and quick relaxation period result in minimal signal in MRI scans, making it challenging to capture. Several algorithms like Ultrashort echo time, sweep image with Fourier transformation (Swift), can better visualize the hard tissues of teeth [65-68].

Research examined the efficacy of MRI on individual fractured teeth having a threshold for detection of approximately twenty m, and their research has additionally demonstrated that concurrent 3D imaging of both the soft and hard oral structure is conceivable [67, 68]. MRI can easily detect micro cracks. However, because of the high cost and operational difficulty of MRI, it is not frequently used to diagnose cracked teeth [65, 69].

Treatment

The location and degree of the crack determines the course of treatment for a broken tooth. If the fracture can be seen in X-rays or cone beam images, then that needs attention and treatment. But if the patient is symptomatic but the crack cannot be seen in the X-rays and not even in CBCT, further evaluation is needed that might require a microscopic evaluation.

Various treatment options for a cracked tooth

Cosmetic contouring

Rounding and polishing of the rough edges smooths out the broken tooth.

Bonding

A composite restoration can easily treat a crack line.

Veneer (Porcelain or composite)

A veneer over the cracked tooth is a great treatment option that is more permanent as compared to a composite restoration, if there is sufficient ferrule to place a crown.

Crown

A porcelain or ceramic crown is often used when there aren't enough natural teeth for a veneer.

Root canal

Used when the crack extends into the pulp and hence nerve involvement.

Extraction

Used when the crack extends into the pulp and hence nerve involvement.

In some cases, like when the crack does not hinder the esthetics, or there is no pain, or the crack is very minute (also called a hairline fracture), then no treatment would be necessary and just watch the crack over time.

Prevention

Prevention is better than cure. Though it is not possible to

prevent every crack from happening but there are many precautions that can be easily taken by anyone to minimize the chances of a crack. For example, by being mindful of what is being eaten and avoiding certain foods esp. very hard ones, avoiding chewing ice, good oral hygiene routines and timely dentist visits, and protecting oral tissues with a mouth guard for sports and nocturnal clenching and grinding. Once a crack has formed in the dental hard tissues, it cannot heal on its own but a timely treatment of the same would prevent a further progression of the width and depth of the crack and hence preventing a subsequent extensive damage to the tooth or possibly an infection.

Conclusion

Traditional clinical treatments and medical imaging techniques have all been used in the diagnosis of broken teeth. A summary of various medical imaging technologies is provided in this review article. Oral X-ray radiographs, one of the X-ray-based techniques, can accurately diagnose commonly fractured teeth with a very low radiation dosage. CBCT, a 3D imaging diagnostic technique is highly beneficial in the detection of cracks. Regarding micro-CT, despite having the highest spatial resolution, its significant radiation exposure makes it unsuitable for use in clinical diagnosis. Due to their non-radiative and non-invasive qualities, other new medical imaging modalities like MRI and ultrasound have also been researched. The aforementioned techniques are currently exclusively tested on teeth that are isolated or artificial considering they involve an intricate interaction process and trained expertise, and this could restrict the practicality of these modalities. OCT has several benefits including better image quality, superior image resolution, being a safe and noninvasive method, and images captured immediately in real time. Because of the above-mentioned advantages of OCT, it is now becoming a preferred adjunctive modality for cracked teeth detection. Some of the current experts and research scholars in this field are approaching modalities such as OCT, and CBCT as the primary topics of research in the field of cracked teeth detection. With additional focused research on these methods, the researchers hope to achieve advanced precision in their results.

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Conflicts of Interest

The author declares no conflict of interest.

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