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A Review of Root Fractures: Diagnosis, Treatment and Prognosis

Abstract: Tooth fractures (crown or root fractures) are commonly encountered emergencies in a dental clinic. Root fractures are defined as fractures involving the dentine, cementum and pulp. They are broadly classified as horizontal and vertical root fractures. They may be clinically challenging cases to treat as, usually, treatment of such cases requires an interdisciplinary/multidisciplinary approach for complete rehabilitation of teeth. For a successful outcome, it is imperative to arrive at an appropriate diagnosis and design a treatment plan accordingly as soon as possible. This review article discusses the various types of root fractures, their diagnosis and treatment, along with the factors affecting their healing and prognosis.

Clinical Relevance: Treatment of root fractures depends on a number of factors such as, position of fracture line, mobility of tooth and pulpal status. Thus clinicians must have thorough knowledge and adequate clinical experience to treat them properly.

Dent Update 2011; 38: 615–628

Traumatic injuries to a tooth can vary in severity from a simple enamel infraction to a complete ex-articulation of tooth (avulsion). Among these injuries, tooth fracture (crown fractures, crown-root fractures and root fractures) are considered to be the third most common cause of tooth loss.[1] Of particular interest to clinicians (and clinically challenging) are the cases of root fractures as their management may involve an interdisciplinary/multidisciplinary treatment approach.[2] Root fractures are defined as fractures involving the dentine, cementum and pulp.[1] They comprise 0.5 to 7% of the injuries affecting the permanent dentition and commonly occur between the age group of 11 to 20 years.[3,4,5] Root fractures can be broadly classified as (Table 1):

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- Horizontal (transverse); or
- Vertical.

Horizontal root fractures are the most common type and occur mainly in the anterior region of the maxilla (maxillary central incisor region) in fully erupted teeth with complete root formation, owing to a frontal impact.[1,3,6] They occur most commonly in the middle-third and rarely in the apical- and coronal-third of the root.[6,7] They show

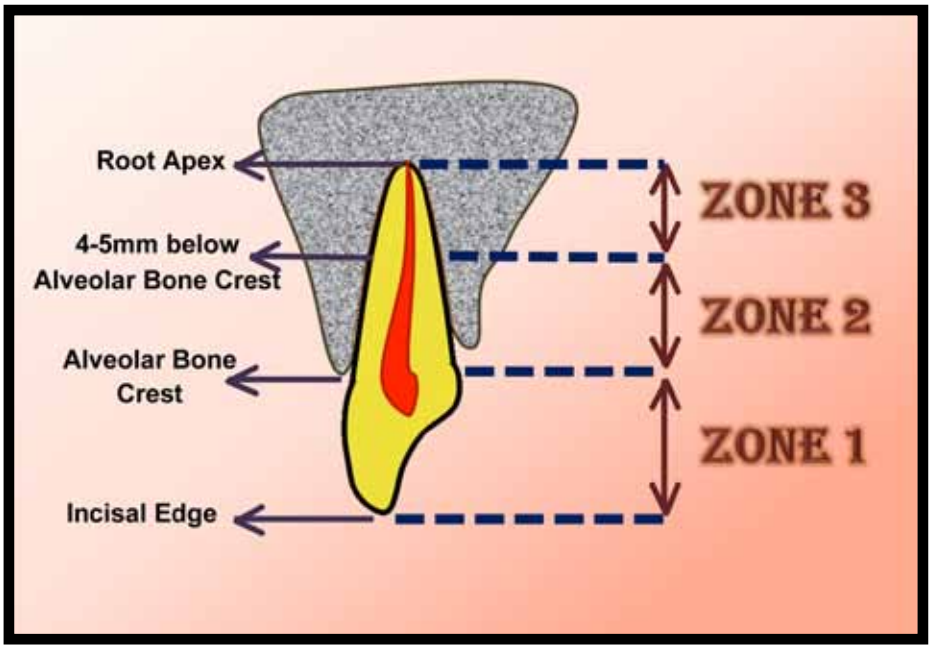


Figure 1. Classification of transverse root fractures depending on the position of the fracture line.

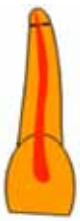
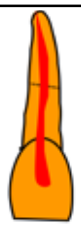
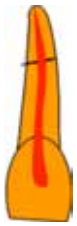
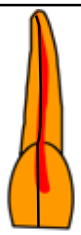
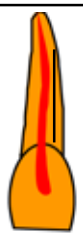
	Types	Sub-Classification		
ROOT FRACTURE	Horizontal Fractures	Number	 Simple	 Multiple
		Location	 Cervical	 Middle  Apical
		Position of Coronal Fragment	 Not Displaced	 Displaced
		Extent	 Partial	 Total
	Vertical Fractures	Fragment Separation	 Complete	 Incomplete
		Fracture Position	 Supraosseous	 Intraosseous

Table 1. Classification of horizontal and vertical root fractures.

the highest chances of preservation of pulp-vitality as compared to other luxation injuries.[8]

Another rare type of root fracture is a vertical root fracture that extends through the long axis of the root toward the apex. An interdisciplinary and/or multidisciplinary approach may be required for the functional and aesthetic rehabilitation of the tooth following such fractures.[2,6,9] This review article discusses the clinical and radiographic features, diagnostic criteria, available treatment options and prognostic factors influencing the healing of these root fractures.

Horizontal root fractures

Classification

Horizontal/transverse root fractures are most commonly seen in young adults due to direct physical trauma in the anterior region. They can be further sub-classified on the basis of:

- Location of fracture line (cervical, middle and apical);
- Extent of fracture (partial and total);
- Number of fracture lines (simple, multiple and comminuted);
- Position of coronal fragment (displaced and not displaced).

Depending on the position of the fracture line, transverse root fractures can also be classified into three zones[10] as follows (Figure 1):

- Zone 1 – extends from the occlusal/incisal edge to the alveolar bone crest.
- Zone 2 – extends from the alveolar bone crest to 5 mm below.
- Zone 3 – extends from 5 mm below the alveolar bone crest to the apex of the root.

These zones are analogues to crown fracture, cervical-root fracture, and middle/apical root fracture, respectively.

Aetiology

The most common reason for root fractures in the permanent dentition is physical trauma caused during falls, fights or sporting events.[3] Any object striking the teeth may also lead to a similar injury. As fights and sporting activities are more common in the first and second decade of life, an increased prevalence of root fractures is observed in a similar age group (11–22 years).[1] Usually, horizontal root fractures are observed in anterior teeth with direct trauma. In posterior teeth, it usually occurs as a result of indirect trauma.

Figure 2. Pulse-oximeter.

In addition, root fractures may occasionally be caused by parafunctional habits, traumatic occlusion, extensive tooth decay and iatrogenic causes.

History

The diagnosis begins by recording the demographics of the patient and taking a brief history of the traumatic event:

- Time and place of event;
- Reason for the injury (eg fights or sports);
- Any previous dental injuries;
- Any spontaneous pain or sensitivity; and
- Other associated symptoms following injury (unconsciousness, drowsiness, vomiting or headache).

Equally important is an overview of the general systemic health of the patient (allergic reactions, epilepsy or bleeding disorders)[1] and a neurophysiologic examination of the patient. Traumatic injuries to teeth can be associated with injuries in the head and neck region, presenting with subtle signs and symptoms but with serious neurological consequences. Therefore, it is important to do an initial neurological examination and evaluation of the patient, along with the orofacial structures.

Clinical examination[1]

Fractures in the middle-third of the root occur with higher frequency, while fractures of the apical- and cervical-thirds occur with equal frequency. Fractures in the apical-third of the root do not show signs of displacement or mobility. Teeth with middle-third fractures are usually slightly extruded with displacement in the lingual direction and lateral luxation of the coronal segment.[1] In cervical-third fractures extending below crestal bone, the crown is usually present with minor mobility owing to attachment of the periodontal fibres to the portion of root that has fractured off with the crown.[1] In anterior teeth, with fracture line above the crestal bone, the crown is usually extremely mobile or dislodged. In posterior teeth, clinical presentation is of one rigid cusp and one mobile cusp. The tooth may be tender to percussion and/or palpation and show transient crown discoloration.[11] A thorough visualization of the subgingival area is also important to detect any fracture line.

Pulpal status

Initially, sensibility and vitality testing may give negative results due to transient or permanent pulpal damage inflicted by trauma.[6] A routine follow-up is required to monitor the pulpal status continuously.[11,12] More recently, the use of a pulse-oximeter was recommended to evaluate the pulpal status of a recently traumatized tooth (Figure 2). This has better sensitivity and specifity than electrical and thermal tests[13] and gives a constant positive vitality reading with time in cases of recently traumatized teeth.[14]

Radiographic examination[1,11]

Radiographic examination is indispensable for the confirmation of root fractures. The fracture line is oriented obliquely in the apical- and middle-third of the root and more horizontally oriented in the cervical-third. Therefore these fractures are normally visible only when the central beam is directed within a maximum range of 15–20° of the fracture plane. Any deviation from the fracture plane shows the fracture line as an ellipsoid structure mimicking an intermediary fragment. In addition to the conventional periapical radiograph, two additional periapical radiographs (one with a positive angulation of 15° to the fracture line and the second with a negative angulation of 15° to the fracture line) should be exposed.[1] Other suggested protocols to visualize the fracture line accurately are:

- Processing three-angled radiographs at 45°, 90° and 110°.[15]
- A steep occlusal exposure along with two conventional periapical bisecting-angle exposures.[9]

In addition to the views listed above, occlusal radiographs may be required to disclose fractures in the apical-third of the root, although cervical-third root fractures are better visualized with periapical radiographs.[9] Horizontal root fractures are also often associated with concomitant fracture of the alveolar process (mandibular incisor region).[1]

Treatment

Root fractures with minor insults and/or damage to pulp (hair line fractures) either lead to concussion injury or non-vitality. In such cases, vitality tests should be performed on a regular basis and the tooth kept under constant observation as there are high chances of re-establishment of pulp vitality via revascularization. In cases of complete horizontal fractures, the treatment principle is the same as for any other fracture, ie reduction of displaced fragment followed by immobilization.[1] Often an interdisciplinary/multidisciplinary approach is essential for the functional and aesthetic rehabilitation of a tooth.[2] Treatment advocated in a particular case is determined by the extent of subgingival fracture, remaining coronal tooth structure, location of fracture line, pulp vitality and length and morphology of the roots.[6,9] In cases of severe neurovascular damage, unfavourable outcomes such as pulp canal obliteration and pulpal necrosis can occur.

Management of root fractures

Management of root fractures can be divided into treatment of apical-third, middle-third and cervical-third fractures (Table 2).

Apical-third fracture[1,9]

In the case of apical-third fractures of the root, there is usually no mobility and the tooth may be asymptomatic. Also, it has been observed that the apical segment of a transversely fractured tooth remains vital in most of the cases. Thus no treatment is required and a watch and observe policy is advocated. If the pulp undergoes necrosis in the apical fragment, surgical removal of the apical fragment is indicated.

Middle-third fracture

The treatment advocated is immediate repositioning of the displaced

	Position of fracture line	Treatment	
MANAGEMENT	Apical	Watch and observe	
		Retain the segment	Pulp vital
		Surgical extraction	Pulp necrosis
	Middle	Reduction and stabilization	
		Healing	70-80% of intra-alveolar fractures
		Root canal treatment	Pulp necrosis
	Cervical	Poorest chances of healing	
		Reduction & stabilization	Coronal segment is present Fracture below the alveolar bone crest
		Reattachment	Coronal segment is present Fracture at or above the alveolar bone crest
		Post crowns	Coronal segment is absent (lost) Fracture above the alveolar bone crest
		Periodontal surgery	Sufficient root length Fracture below the alveolar bone crest Aesthetic result is not required
		Orthodontic extrusion	Sufficient root length Fracture below the alveolar bone crest Aesthetic result is required
		Surgical extrusion	Emergency treatment Fracture below the alveolar bone crest
		Extraction	Other conservative treatments not possible Other conservative treatments failed Poor prognosis

Table 2. Management of apical-third, middle-third and cervical-third root fractures.

fragment followed by application of a passive splint. It can be done by simple digital manipulation (finger pressure), or an orthodontic intervention may be required for proper alignment. Resistance to repositioning can occur owing to fracture of the labial socket wall and it should be repositioned before the reduction of root fracture. The position of reduced segments is checked radiographically. Following reduction, a passive splint is applied for a period of 4 weeks to ensure sufficient hard tissue consolidation.[1,11] The advocated splinting methods include the use of stainless-steel wire resin-based composite splints or titanium trauma splints (TTS). These are 0.2 mm thick rhomboid mesh structures of titanium that can be easily adapted and stabilized on the teeth. They require less application time, are easy to remove and clean and have been considered to be more comfortable.[16]

Cervical-third fracture

Treatment options are decided upon by the position of the fracture line, length of the remaining root segment and the presence or absence of a coronal segment. Chances of healing with calcified tissue is poorest in cervical-third fractures.[1,17]

Reattachment

In cases where the coronal segment is available and fracture occurs at or coronal to the level of alveolar bone crest, reattachment of the fractured segments can be attempted.[18,19] This is done with the help of light transmitting or fibre-reinforced posts and resin-based composite material. Successful reattachment of a fractured root fragment has been reported with an intraradicular resin-based composite reinforcement technique that reinforced the weakened root with resin-based composite, avoiding the need for fixed prostheses, implants or extraction.[20]

Conventional treatment

Cervical-third fractures below the alveolar bone crest may be treated with the conventional reduction and stabilization approach. It is shown that healing is possible with this conservative approach.[1,21] Splinting for cervical-third root fracture should be carried out for a period of 4 months.[11] In patients with optimal oral hygiene, permanent fixation of the coronal fragment to adjacent teeth at the proximal contact areas with a resin-based composite or reattachment of fractured segments can also be tried. Care should be taken that occlusal interferences and load on the injured teeth should be kept to a minimum.

Post crowns

Post crowns with subgingival

Figure 3. Crown-lengthening procedure. It involves removal of 1 to 2 mm of crestal bone adjacent to the deepest extent of the fracture.

a

b

Figure 4. (a, b) Modified Hawley's appliance used for extrusion of UR3: **(a)** pre-extrusion and **(b)** post-extrusion view.

margins or false shoulders are indicated in cases where the coronal segment is absent (lost), the fracture line is above the alveolar bone crest and the apical root segment has sufficient length. In cases where exposure of crown margins is required, a simple gingivoplasty or an apical positioned flap surgery is performed.[1,6,9,22]

Other treatment alternatives

If the fracture line extends below the level of the alveolar bone crest and the apical root segment has sufficient length, the following three possible treatment alternatives are available:

- Crown lengthening (periodontal surgery);
- Orthodontic extrusion;
- Intra-alveolar transplantation of the fractured tooth (surgical extrusion).

Crown lengthening (periodontal surgery)

Crown lengthening is performed if the fracture line is not more than 1–2 mm below the alveolar bone crest. This procedure involves removal of 1–2 mm of crestal bone adjacent to the deepest part of the fracture and restoring the normal sulcus depth of 2 mm (Figure 3). It usually leads to apical shifting of gingival margin which may compromise aesthetics. Periodontal and osseous recontouring allows exposure of the fracture margin and sufficient root surface to give an acceptable restorative finish line.

Orthodontic extrusion

This is also known as forced eruption, orthodontic eruption, vertical extrusion or assisted eruption. It is carried out in cases where the fracture line extends deeply in the interproximal or labial surface (up to 6 mm below the alveolar crest) and when crown lengthening would be unaesthetic.

For a successful extrusion and post-treatment restoration, the distance from the fracture line to the apex should not be less than 12 mm and a crown-root ratio of approximately 50:50 must be obtained. This technique involves application of traction forces to the tooth, causing vertical extrusion of the root and marginal apposition of crestal bone (Figure 4). The gingiva, epithelial attachment, and newly formed crestal bone are also extruded, along with the tooth, leading to a coronal shift of the marginal gingiva. Thus there is no loss of any bone or periodontal support. But this coronal shift of gingiva has the following disadvantages:

- It partially masks the extent of root extrusion;
- Disparity in levels of epithelial attachment and bone between the adjacent teeth;
- Relapse of the extruded fragment.

Therefore, at the end of the procedure, a conservative periodontal surgery is necessary to correct any discrepancy followed by a stabilization period of 7–14 weeks before the orthodontic appliance is removed.[1] The techniques used for orthodontic extrusion include the use of removable or fixed orthodontic appliances.[23,24]

Intra-alveolar transplantation of the fractured tooth

This is mainly performed in cases where time and money are the major determining factors. It is carried out for patients who are treated on an emergency basis, having severe luxation of the fractured root. In this technique, the tooth is carefully extruded to the required position by marginal luxation and stabilized by interdental suturing and surgical dressing.[25,26] If the fracture line is more apical on the labial side, a rotation of 180° is given before fixation.[27] With this method the bone support around the root is usually lost.

Extraction[1,9]

The time and cost of potential restoration of a horizontally fractured tooth must be weighed against the alternatives of implant, fixed or removable prosthesis. In cases where conservative treatment is not possible, the fractured tooth should be extracted without causing any damage to the alveolar processes, especially in the labio-lingual direction. Usually, preservation of the apical fragment is recommended as it normally contains vital pulpal tissue. This prevents or retards resorption of the alveolar process. With time, roots get covered with a new layer of cementum and a thin layer of new bone along the fractured surface. If removal of the apical fragment is eventually necessary, it should either be done via the socket with minimal sacrifice of labial bone or a surgical removal, if necessary.

Follow-up

Clinical and radiographic examination should be done at 4 week, 6–8 week, 4 month, 6 month, 1 year and 5 year intervals. Patients should be advised regarding the care of teeth that have received an injury.[11] Use of a soft brush and 0.1% chlorhexidine rinse prevents accumulation of plaque and debris and helps in maintaining good oral hygiene.

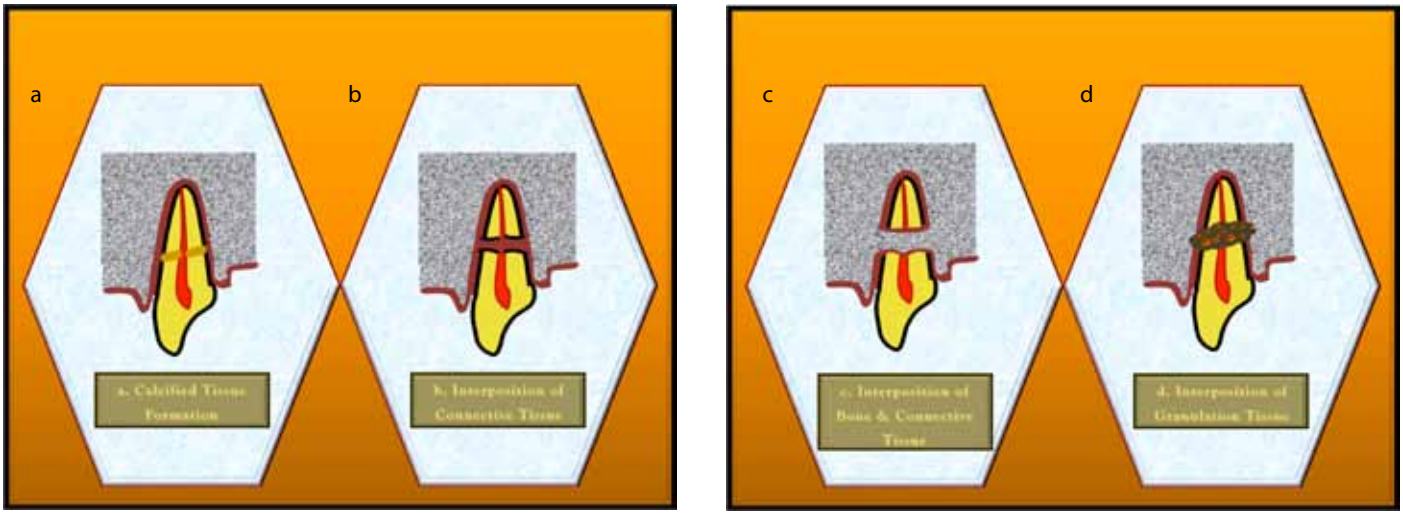


Figure 5. (a–d) Four types of healing in transverse root fractures: **(a)** healing by hard tissue (calcified tissue); **(b)** healing by interposition of connective tissue; **(c)** healing by interposition of bone and connective tissue; and **(d)** healing by interposition of granulation tissue.

Healing in root fractures

Indicators of favourable outcomes following treatment of root fractures include:

- Asymptomatic status;
- Positive response to pulp testing;
- Continuing root development in immature teeth;
- Signs of repair between fractured segments; and
- Absence of apical periodontitis.

About 80% of properly treated root fractures heal successfully. Pulp vitality is usually maintained after root fractures, causing spontaneous healing in 70–80% of intra-alveolar root fracture cases.[1,28] Healing following fracture is initiated at the pulpal and periodontal ligament side, creating two types of wound healing response, occurring either independently or competitively of each other. Healing of transverse root fractures involves the union of fracture segments by either hard, calcified tissue (and occurs rarely), interposition of connective tissue (which occurs more commonly), interposition of bone and connective tissue, or interposition of granulation tissue[1] (Figure 5). Andreasen *et al*[29] observed 30% of the cases with root fractures healed by hard tissue fusion of the fragments, 43% by interposition of connective tissue (PDL), 5% by interposition of connective tissue (PDL) and bone and 22% showed signs of inflammation and pulp necrosis. The factors that influence healing and prognosis are as follows:[1,30]

- Position and mobility of coronal segment after trauma;
- Status of the pulp;
- Position of the fracture line;
- Treatment time;
- Communication with the oral environment;
- Age;
- Gender.

Position and mobility of coronal segment after trauma

Increased dislocation and mobility result in a decreased prognosis. In concussion, a high rate of hard-tissue healing is observed, whereas in cases of luxation, healing with connective tissue is high.[31] Immobilization should be done as soon as possible for an optimum consolidation and repair across the fracture line. Optimal repositioning and use of passive flexible splint favours healing.[1]

Status of the pulp

A vital pulp and positive pulp sensibility at the time of injury are positively related to faster healing and hard tissue repair of the fracture. Pulp in the apical segment of the fractured tooth is vital in almost all cases.

Position of the fracture line

Middle-third fractures are considered to have the best prognostic value. The chance of healing with calcified tissue and survival is poorest when the fracture line is very close to the gingival crevice.[29] Zachrisson and Jacobsen[32] observed that the location of the fracture line does not influence the outcome, except for fractures that occur too close to the alveolar bone crest (as the tooth support is compromised).

Treatment time

There is apparently no definitive proof of a relationship between treatment time, ie time taken until treatment is initiated, and prognosis.

Communication with the oral environment

If communication develops between the gingival sulcus and the fracture site the prognosis is poor because of bacterial contamination[6,33]

Age

Young age and immature root formation are increasingly related to pulpal healing and hard tissue formation at the fracture site due to the increased size of pulp and vascularity.

Gender

Girls showed more frequent hard tissue healing than boys as they usually experience less severe trauma and at an earlier age.[30]

Other factors include:

- Diastasis between the fracture segments;
- Presence of restoration at the time of injury; and

- Presence of marginal periodontitis.[1]

However, in certain cases, the follow-up examinations may show deviations from the normal pulpal and periodontal healing, leading to pulpal necrosis, pulp canal obliteration and root resorption.

Pulp canal obliteration

Partial or complete obliteration of the pulp canal with slight yellowing discoloration of the crown is a common finding after root fracture.[1] It is seen in 69–73% of the teeth.[31,32] A revascularization process in the coronal pulp is initiated if the pulp is severely stretched at the fracture line. In the presence of sterile conditions, this results in obliteration of the coronal pulp canal. Obliteration of the apical root canal is commonly observed in cases of calcified tissue healing. However, obliteration of both apical and coronal segments is seen in cases with interposition of connective tissue and interposition of connective tissue and bone.

Pulpal necrosis[1]

Bacterial entry in the coronal pulp results in pulp necrosis, with accumulation of inflamed granulation tissue between the two root fragments. It is seen in about 25% of root-fractured teeth. It is usually detected within the first 2 months of trauma. Contributing factors for pulpal necrosis include:

- Displacement of the coronal fragment;
- Use of rigid splints;
- Completed root formation at the time of injury; and
- Presence of marginal periodontitis.

Proposed treatment for the management of pulp necrosis in root-fractured teeth is long-term calcium hydroxide ($Ca(OH)_2$) therapy,[34] followed by conservative endodontic treatment of coronal fragment alone, or both the fragments (coronal and apical). Root canal treatment should be started within 7–10 days for a mature apex. In cases of immature apices, apexification should be done initially, followed by root canal treatment. Long-term $Ca(OH)_2$ therapy has a weakening effect on dentine and it may take several months for hard tissue formation. More recently, the use of MTA has been recommended for horizontal root fractures for faster and better healing to occur.[35]

Root resorption[1]

At times during the initial healing, pulp and surrounding hard tissues can stimulate an inflammatory response and trigger the activation of osteoclasts, resulting in root resorption. It is found in approximately 60% of root-fractured permanent incisors. It is detected within the first year after injury and resolves by itself in 1–2 years. Either it begins at the periphery of the fracture line adjacent to the periodontal ligament, or centrally within the root canal. All resorptive defects usually heal by interposition of connective tissue between the fragments. The types of root resorption seen are external surface resorption, external inflammatory resorption, external replacement resorption, internal surface resorption and internal tunnelling resorption.

Vertical root fractures (VRF)

Vertical root fractures are tooth fractures that run along the long axis of the tooth or deviate in a mesial or distal direction. They usually occur in older patients in posterior teeth due to iatrogenic causes. The fracture line extends through the long axis of the root towards the apex.[12] The prevalence of VRF ranges from 2–5% of crown/root fractures.

Classification

Vertical root fractures (VRFs) are classified either on the basis of separation of the fragments (complete or incomplete) or on the basis of relative position of fracture to the alveolar crest (supraosseous and intraosseous).[36]

Complete fracture

When total separation is visible or fragments can be moved independently.

Incomplete fracture

When there is an absence of visible separation and segments can easily be separated by an instrument.

Supraosseous fracture

This terminates above the bone, and does not create a periodontal defect.

Intraosseous fracture

This involves the supporting bone, creating a periodontal defect.

Aetiology

Restorative treatment

Crown-root and root fractures, especially vertical root fractures, are seen in teeth that have been extensively restored. Large restorations, forceful seating of crowns, intracoronal restorations (inlays), and the placement of pins can cause root fractures due to wedging action.[37]

Endodontic treatment

Mechanical weakening of the tooth structure occurs during access cavity preparation, whereas cleaning and shaping of root canals increases the chances of tooth fracture.[38] Placement of a crown or pulp removal prevents the local dentinal deformation, raising the threshold of perception for loading. This increases considerably the mechanical forces applied to the pulpless tooth as compared to the intact tooth. Vertical root fractures commonly occur in endodontically treated teeth.[39] The incidence of root fracture increases as the mesio-distal diameter of the root decreases (maxillary second premolar, mesiobuccal roots of maxillary molars, mesial roots of mandibular molars).[40] Root canal obturation and post placement can also lead to root fractures, especially in the apical region.[39,41–43] The use of screws and posts is another cause of fracture due to wedging effects. Tapered and threaded posts generally produce the highest root fracture incidence (7%), followed by tapered and parallel posts.[44] Fractures with tapered posts occur at the coronal-third of the root and, with parallel posts, occur at the apical-third of the root. Also, stresses from cementation of posts, due to hydrostatic pressure of cement, are likely to cause relative deformation of roots.[45] The volume of posts may expand in three-dimensions, as a result of deposition of corrosion products on their surface giving rise to longitudinal root fracture.[46]

Parafunctional habits

Non-carious, non-endodontically treated and unrestored posterior teeth may occasionally fracture due to repetitive excessive occlusal forces, leading to 'fatigue root fracture'.[47,48] This may be observed in individuals with heavy masticatory musculature, habits such as chewing ice and abrasive foodstuffs consumption and parafunctional habits.[36] The compounding

effects of all these increases the possibility and risk for vertical root fractures.

Diagnosis of vertical root fractures

The fractured tooth may have an extensive carious lesion, large failing occlusal restoration, or wear facets on teeth and restorations.[36,49] In posterior teeth, VRF propagate in a crown-down direction, with the fracture line being aligned mesio-distally. Iatrogenic VRF occurs from inner to outer root surface, and is generally aligned in a facio-lingual direction. Intraosseous fracture creates deep, narrow, sharply defined and isolated periodontal pockets ('precipitous pockets').[46] Patients usually complain of pain on mastication. Other symptoms include gingival inflammation, mobility of fragments and presence of sinus tract or fistula. Initial radiographic examination may reveal unilateral thickening of PDL along the fracture side of the root. As the fracture advances, a characteristic diffuse radiolucency *(or halo)* is seen surrounding the tooth root uniformly.[50] Other radiographic features include:

- Existence of a fracture line;
- Separated root fragments;
- Space beside a root filling;
- Double images of external root surface; and
- Vertical bone loss.[51]

Sometimes the VRF is associated with displacements of apical portions of the root.[52] At times the fracture line may be invisible and can only be detected by a tooth sloth, a burlew disk, transillumination test, disclosing dye, surgical exploration, or by removal of an existing restoration.

Treatment

A variety of approaches have been attempted and used to treat the VRF, including:

- The use of cyanoacrylates;[53]
- Glass-ionomer cement with guided tissue regeneration therapy;[54]
- Adhesive resin cement (4-META/MMA-TBB);[55]
- Repositioning; and
- Fixation with wire[56,57] and mineral trioxide aggregate.[58]

However, in most cases of VRF in anterior teeth, extraction is the only available treatment option. For posterior teeth, Luebke[36] has proposed four basic categories of treatment.

1. Treatment Plan 1A

For incomplete, supra-osseous fractures with viable pulp and no radiographic changes or periodontal defects. Restore the tooth with full coverage temporary crown and evaluate after 3 months. If the patient is asymptomatic, a permanent crown is cemented with polycarboxylate or glass-ionomer cement. If the pulp degenerates, additional treatment, as outlined in Plan 1B or Treatment Plan 2 may be indicated.

2. Treatment Plan 1B

For incomplete supraosseous fractures with non-viable pulp but no radiographic changes or periodontal defects. Restore the tooth with a full coverage stainless steel crown and initiate calcium hydroxide therapy. Recall the patient at 3-month intervals. Following 9–12 months of calcium hydroxide therapy, if the bone level is unchanged, endodontic therapy is performed and a permanent crown is placed. In case a pocket develops along the fracture line, switch to Treatment Plan 2.

3. Treatment Plan 2

For incomplete intraosseous fractures with non-viable pulp and a periodontal pocket along the fracture line. Exploratory surgery is indicated for the visualization of the fracture line and the osseous defect. If the fracture line stops short of the osseous defect, the required periodontal surgical procedure may be carried out to restore the defect. Depending on the status of the pulp, Treatment Plan 1A or 1B is initiated. In the case in which the fracture line extends beyond the osseous defect, Treatment Plan 3 can be initiated.

4. Treatment Plan 3

For complete intraosseous fractures with non-viable pulp, bone loss and periodontal pocket. For single-rooted teeth, extraction is indicated. In a multi-rooted tooth where fracture is confined to one root, or if it passes through a furcation, either root amputation, hemisection or extraction is indicated.

Conclusion

The treatment of root fracture may be a painstaking job for both dentists and patients. Therefore, an evidence-based clinical approach should be followed for the successful treatment of root fractures. The clinician should have a thorough knowledge of aetiological cause of fracture, classic signs and symptoms of fracture, availability and applicability of diagnostic methods, differential diagnosis, and factors determining the prognosis, so as to arrive at an appropriate diagnosis and design a suitable treatment protocol. This helps in distinguishing between restorable and non-restorable fractures. A functional and aesthetic outcome following treatment is achieved by a combined therapy, including restorative, endodontic, prosthodontic, periodontal and orthodontic therapies. A regular follow-up of teeth is required to evaluate the success of treatment and to do the necessary alterations in the suggested treatment protocol, if indicated. The pros and cons of a tedious and long conservative therapy should always be weighed against the option of extraction and replacement with other fixed prosthesis.

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