KEY WORDS
Dental trauma, fractures, root fracture, crown fracture, alveolar fracture

LEARNING OBJECTIVES
- To highlight a systematic examination and relevant special investigations for traumatic dental injuries
- To understand the importance of timely and accurate diagnosis of dental and alveolar fractures
- To illustrate the management of various traumatic dental fracture injuries

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DENTAL TRAUMA: ASSESSMENT AND ACUTE MANAGEMENT OF FRACTURES

ABSTRACT

Acute dental trauma is unscheduled and presents infrequently to the majority of practitioners. Therefore, a consistent, logical and systematic process for examination, prioritisation and management is imperative for all sustained injuries to have an optimal outcome. Fractures are a frequent sequela to dental trauma and can involve any aspect of the tooth structure or supporting alveolar bone. While some minor crown fractures may initially seem inconsequential, they may be a subtle indication to a more serious underlying root fracture. Concomitant injuries and injuries that have been initially missed are generally associated with poorer outcomes. The time sensitive management of traumatic dental injuries aims to preserve pulpal and periodontal health where possible. The follow up period for tooth or alveolar fractures are important to allow for early intervention if pathology develops.

Introduction

Dental trauma encompasses any injury to the oral and maxillofacial region which causes damage to the teeth or the supporting structures. Mechanisms of injury can range from interpersonal violence to falls and sports injuries. When the force of trauma exceeds the elasticity of the supporting bone, fractures of the teeth and alveolus can occur.[1] There is huge variability in the presentation and extent of dental trauma, particularly fractures as concomitant injuries. Uncomplicated crown fractures are the most common occurring in approximately 64% of injuries.[2] Comparatively, alveolar fractures are less common and tend to present more frequently in adults than children.[3]

When undertaking an examination following dental trauma, a systematic approach is prudent to reduce the risk of any missed or wrong diagnoses which may negatively impact patient outcomes.[4] A thorough extra-oral and

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intra-oral hard and soft tissue exam looking for evidence of fractures (e.g. step deformities, mobile segments or embedded tooth fragments) should be undertaken. Relevant special investigations including at least two differing radiographic angulations are required to prioritise a comprehensive list of diagnoses to allow timely management and definitive treatment. Communicating these to the patient as early in the process as possible helps to manage patient expectations regarding function, discomfort and aesthetics.[5]

The management of tooth fractures is dependent on the location and extent of the dental or alveolar fracture as well as the stage of tooth development.[6] This article will describe the management of teeth with closed apices, however every attempt should be made to preserve pulpal vitality irrespective of root development given the long term endodontic and mechanical complications of an immature apex.[7]

Examination

Examination should commence with a detailed account of the accident and a full medical history. The mechanism of action is important to exclude non-accidental injury in both paediatric and adult patients with further investigation if there are concerns.[8] This process can be facilitated by an accompanying adult if the patient is distressed. Ensure any signs of head injury (e.g. nausea, dizziness, amnesia, confusion or loss of consciousness) are excluded, otherwise advise the patient to attend the emergency department for assessment.

Thorough documentation is important both dentolegally and to provide accurate temporal comparisons at subsequent visits. Early identification of any deterioration in the pulpal or supporting tissues is only possible with long term clinical follow up data. The summary tables in the "Fracture injuries assessment and management" section (Tables 3–10), allow for simple and systematic recording of the findings.[9] Similarly, clinical photography improves the quality of patient records and allows subsequent practitioners to understand the initial injury presentation. Dentolegally, photographs are the gold standard for documenting traumatic injuries.[10]

Figure 1: Extra-oral examination shows lacerations, abrasions, swelling and damage to the dentition that require noting. In particular, the laceration to the lower lip requires careful examination as it could harbour tooth fragments or foreign bodies

An extra-oral exam may require the patient's face and oral cavity to be cleaned with saline and gauze before a full appreciation of the injuries becomes clear (Figure 1). If, during the examination, the clinician becomes concerned that there may be a facial fracture, this should be prioritised and an urgent referral to an oral and maxillofacial surgery (OMFS) unit is recommended.[11] In the case of an avulsion, if the tooth cannot be safely re-implanted, it should be stored in milk and brought with the patient to the OMFS unit. Table 1 summarises the key clinical findings of extra-oral examinations and their implications for treatment.

An intra-oral examination can be uncomfortable and local anaesthetic may be necessary. When assessing multiple teeth, it is important to note there may be overlapping or concomitant diagnoses, therefore ensure to keep a concise list of the findings for each tooth (Figure 2).[12] Table 2 summarises the key clinical findings of intra-oral examinations and their implications for treatment.

Special tests

Pulp testing

Pulp tests generally assess the status of the pulp nerve fibres using thermal or electric methods. They do not indicate the health of the vascular supply.[13] Traumatised teeth can test negative for several months after the injury, therefore pulp testing is most useful over a longer period to indicate change rather than a single result.[14] Typically, they are not advised at the initial presentation due to risk of pain and inaccurate readings. It is critically important to compare pulp test results with healthy contralateral teeth as a control and to not mistaken electric pulp test readings as an indication of how vital or not a pulp is – the binary presence of a response or not is more important than the value of the current. The results should always be correlated with clinical and radiographic examinations.

Radiographic examination

Intraoral periapical views using the paralleling technique with at least a second view at a different vertical and horizontal angulation are the first line radiographs.[15] Different angulations in both axes is recommended and will optimise the detection of a root fracture (Figure 4). Periodontal ligament widening in the acute phase is unlikely due to pulpal necrosis but more indicative of a root displacement injury. Further imaging for suspected facial or mandibular fractures is best undertaken by a hospital unit.

Soft tissue radiographs are indicated if there is suspicion of embedded tooth fragments or foreign bodies. This view can be taken at half of the incisor exposure setting by holding a size 2 film lateral to the lips and positioning the tubehead pointing through the lips.

Cone beam computed tomography (CBCT) can provide a detailed view of traumatic dental injuries (TDIs). The European Society of Endodontology position statement[16] and the Safety and Efficacy of a New and Emerging Dental X-ray Modality (SEDENTEXCT) guidelines[17] provide comprehensive guidance and indications for this imaging modality. Alternatively, the patient may have had this imaging

TABLE 1

EXTRA-ORAL EXAMINATION: KEY CLINICAL FINDINGS AND THEIR RELEVANCE

Extra-oral assessment	Description	Implications
Swelling	Soft tissue oedema is common following dental trauma	Can be uncomfortable to examine but may indicate facial fractures. It may also make palpating bony contours more challenging
Contusion	Bruising usually occurs on bony prominences	Bruising can be delayed up to 72 hours which may cause delayed detection of underlying fractures
Abrasions and lacerations	Abrasions and lacerations should be cleaned thoroughly with saline and gauze and assessed for retained foreign bodies	May require a soft tissue radiograph view for retained foreign body or referral to an oral and maxillofacial surgery (OMFS) unit for suturing
Symmetry	Symmetry can be assessed by standing behind the patient while they are sitting up in the chair and by looking down the face	Identification of asymmetry that is not due to swelling may suggest a facial fracture. Proptosis of the eye can suggest retrobulbar haemorrhage. Both indicate an OMFS referral
Palpation of bony contours	Assess bony prominences of the face such as the zygomatic buttress, maxilla and inferior border of the mandible	Step deformity indicates possible facial fracture requiring an OMFS referral
Altered sensation or numbness	Anaesthesia, paraesthesia or dysaesthesia in any region of the face	Suggests bony fracture impinging or stretching a sensory nerve innervating the overlying skin. OMFS referral indicated
Neuromuscular impairment	Ask the patient to scrunch their face, grimace and puff out their cheeks as a simple cranial nerve (CN) exam to determine if the facial nerve (CN VII) is intact	Injury to cranial nerve distribution suggests bony fracture. OMFS referral indicated
Opening	Assess the interincisal distance	May suggest a fracture of the zygoma or condyle requiring OMFS option. Will make access more challenging for an intra-oral examination

Figure 2: Significant dental trauma in a heavily restored dentition shows multiple fractures of natural and prosthetic teeth that could be easily missed without a systematic examination and recording method

carried out in hospital which would be useful to access.

Fracture injuries assessment and management

Clinical assessment may reveal multiple injured teeth and multiple injuries such as alveolar fracture, root fracture or displacement per tooth known as concomitant injuries. Therefore the follow up of the most severe injury should be followed. If the findings do not completely fit with one of the descriptor tables in scenarios one to eight, below (Tables 3–10), consider an alternative diagnosis or second opinion: TDIs are not always immediately obvious.

Scenario 1. Infraction: an incomplete hairline fracture of the enamel

Management

Generally, no treatment required unless the infraction is large enough where flowable composite may be placed to seal the crack.

Follow up

None required unless other concomitant injuries.

Scenario 2. Enamel fracture: a fracture confined to just enamel

Management

- if fragment is present, bond the fragment back into position. Do not

TABLE 2

INTRA-ORAL EXAMINATION: KEY CLINICAL FINDINGS AND THEIR RELEVANCE

Intra-oral examination	Description	Implications
Palpation	Manual palpation of the maxillary and mandibular bony contours	May illicit a step deformity indicative of a fracture
Soft tissue	Carry out an inspection of the intraoral soft tissues	Identify any lacerations or abrasions which may require treatment or indicate fracture
Mobility	Mobility should be assessed using the end of two metal instrument handles, as digit pressure can give erroneous readings	Increased mobility of a single tooth can suggest the presence of a fracture or displacement injury. The movement of adjacent teeth simultaneously en-bloc is pathognomonic for an alveolar fracture
Percussion	Tenderness to percussion using an instrument handle is not generally advised at the acute visit as they can cause further discomfort to patients. At follow up visits it can be more useful	Can suggest periodontal ligament injury including a cervical third root fracture or the development of apical pathology at follow up
Occlusion	Occlusion should be assessed to ensure there is no derangement with equal contact across the dentition in intercuspal position (Figure 3). Asking the patient if their bite feels normal is a useful indicator	Alterations in occlusion is indicative of tooth displacement or a displaced bony fracture

Figure 3: Recently splinted maxillary incisors. The traumatised anterior teeth have enamel-dentine fractures but also luxation injuries that have not been repositioned sufficiently to allow posterior contact

bevel either of the fractured surfaces as this can affect repositioning the fragment
- if fragment missing, either polish the enamel edge or restore with direct resin composite

Follow up
- clinical and radiographic review at six to eight weeks and at one year
- aiming for continued dental development in immature roots, pulp vitality and no resorption

Scenario 3. Enamel-dentine fracture: a fracture confined to enamel and dentine

Management
- if the fragment is present, soak in saline for 20 minutes to rehydrate. Reposition and bond the fragment back in place. Do not adjust/polish the fractured surfaces as this will inhibit accurate relocation of the fractured portion
- if the fragment is missing apply direct resin composite to restore the lost tissue form and function
- provisionalise with glass ionomer cement (GIC) or resin modified GIC if time or circumstances do not permit definitive restoration

Follow up
- clinical and radiographic review at six to eight weeks and at one year
- aiming for continued dental development in immature roots, pulp vitality and no resorption

Scenario 4. Enamel-dentine-pulp fracture: fracture confined to enamel and dentine with pulp exposure

Management
Every effort should be made to preserve pulp vitality irrespective of root development.

- clean the affected area of debris with saline
- begin vital pulp therapy; if possible, apply rubber dam. Using a sterile bur, remove the exposed pulp tissue by 2–3mm or until you see a normal pulp colour, bleeding and no debris
- disinfect the pulp space and achieve haemostasis with 3% sodium hypochlorite solution
- apply a calcium silicate/hydraulic cement on top of the pulp to fill the cavity created and seal with GIC (Figure 8). Avoid mineral trioxide aggregate (MTA) due to the risk of discolouration
- follow the management for an enamel–dentine fracture from here

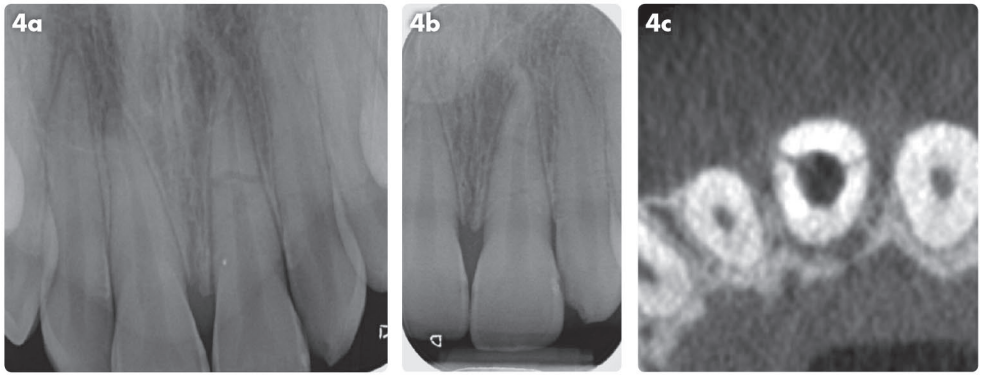


Figure 4: (a) This occlusal radiograph of a maxillary left central incisor shows a clear mid-third root fracture; (b) The periapical radiograph shows much less detail and the fracture could be easily missed; (c) A coronal slice of a cone beam computed tomography (CBCT) shows an oblique crown root fracture of the maxillary right central incisor, note the surrounding bone loss is a subtle additional sign of the fracture

TABLE 3

SUMMARY OF INFRACTION INJURY FINDINGS

Assessment	Findings
Clinical presentation	The patient may or may not be aware of the enamel fracture line
Visual inspection	Hairline enamel fracture, transillumination may aid identification (Figure 5)
Palpation	Usually no step deformities or tenderness
Mobility	Normal
Percussion	Nil – if positive it may indicate a concomitant injury
Occlusion	Normal
Pulp test results	Usually positive, although possibly abnormal in acute phase
Radiographic findings	Normal – but ensure to exclude presence of concomitant injuries

TABLE 4

SUMMARY OF ENAMEL FRACTURE INJURY FINDINGS

Assessment	Findings
Clinical presentation	The patient may have the fragment with them
Visual inspection	Fracture causing loss of enamel only not extending into dentine or root surface (Figure 6)
Palpation	Usually no step deformities or tenderness
Mobility	Normal
Percussion	Nil – if positive it may indicate a concomitant injury
Occlusion	Normal
Pulp test results	Usually positive, although possibly abnormal in acute phase
Radiographic findings	Normal – ensure to exclude concomitant root fracture. Consider soft tissue view if fragment unaccounted for and intra-oral laceration is present

Figure 5: Maxillary left central incisor with enamel infractions at the cervical level. Note the discolouration and adjacent tooth incisal fracture, hinting at a history of dental trauma and possible hidden concomitant injuries

Figure 6: An enamel fracture of the mandibular left lateral incisor which could be easily overlooked due to the avulsion of the maxillary central incisors

Follow up

- clinical and radiographic review at six to eight weeks, three months, six months, and at one year
- aiming for continued root formation and preserved pulp vitality

Scenario 5. Crown–root fracture: a fracture affecting enamel, dentine and cementum

Management

- in an emergency the fractured coronal portion can be splinted to maintain the appearance
- will depend on the extent of the fracture relative to the supporting tissue:
  - supragingival fracture – following coronal fragment removal consider rebonding after resection of gingival tissues from fragment and haemorrhage control using a dual cured luting cement or flowable composite resin. Warn of a guarded prognosis. If this is not possible, a direct or indirect restoration may be

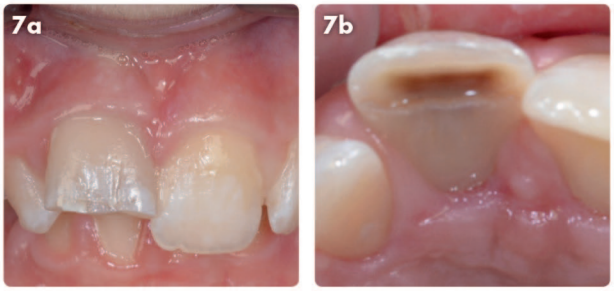


Figure 7: (a) Buccal and (b) occlusal views of a maxillary right central incisor with an enamel dentine fracture

TABLE 5

SUMMARY OF ENAMEL-DENTINE FRACTURE FINDINGS

Assessment	Findings
Clinical presentation	The patient will likely be aware of the fractured tooth and may be experiencing symptoms similar to dentine hypersensitivity. The fractured portion may be unaccounted for
Visual inspection	Loss of tooth tissue exposing dentine but not extending to root surface or pulpal exposure (Figure 7)
Palpation	Usually no step deformities or tenderness
Mobility	Normal
Percussion	Nil – if positive it may indicate a concomitant PDL injury
Occlusion	Normal
Pulp test results	Usually positive, although possibly abnormal in acute phase
Radiographic findings	Evidence of hard tissue loss, exclude presence of concomitant injuries. Consider a soft tissue view if fragment cannot be located and there are soft tissue lacerations

TABLE 6

SUMMARY OF ENAMEL-DENTINE-PULP FRACTURE FINDINGS

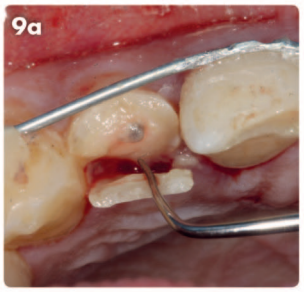
Assessment	Findings
Clinical presentation	The patient will likely be aware of the fractured tooth and may be experiencing symptoms similar to dentine hypersensitivity along with extreme tenderness when touching the tooth. The fractured portion may be unaccounted for
Visual inspection	Loss of tooth tissue with evidence of pulpal exposure (Figure 8)
Palpation	Usually no step deformities or tenderness
Mobility	Normal
Percussion	Nil – if positive it may indicate a concomitant PDL injury
Occlusion	Normal
Pulp test results	Potential abnormal response due to pulpal trauma
Radiographic findings	Crown fracture involving the pulp, exclude presence of concomitant injuries

Figure 8: Maxillary left canine with (a) an enamel-dentine-pulp fracture (complicated crown fracture), and (b) after vital pulp therapy of the superficial inflamed pulp and composite bandage restoration

TABLE 7

SUMMARY OF CROWN–ROOT FRACTURE FINDINGS

Assessment	Findings
Clinical presentation	Possible soft tissue trauma and discomfort
Visual inspection	Assess the extent of the fracture relative to the gingival and alveolar level (Figure 9) by gentle probing under local anaesthetic. The pulp is not exposed
Palpation	Normal
Mobility	If the fragment remains attached to the PDL, it will be mobile
Percussion	Likely to be tender
Occlusion	May be altered if fragment is displaced
Pulp test results	Usually positive, although possibly abnormal in acute phase
Radiographic findings	Loss of coronal tooth tissue with fracture line extending to involve the root surface The extent of fracture may not be fully visualised by a periapical and occlusal radiograph therefore a CBCT could be justified



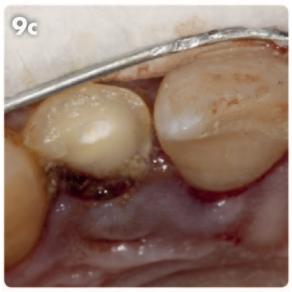


Figure 9: (a) Maxillary right lateral incisor with a crown-root fracture extending subgingivally including pulp exposure; (b) The pulp exposure has been accessed with a clean round bur to create space and resect the inflamed/infected pulp. The cavity was disinfected with sodium hypochlorite and dried with sterile paper points; (c) The cavity was restored with calcium hydroxide and covered with glass ionomer cement (GIC) before considering a definitive restoration at review

indicated dependent on restorability assessment of the remaining tooth tissue
- subgingival fracture, following removal of the fragment
  - gingivectomy with possible ostectomy
  - orthodontic extrusion
  - surgical extrusion
  - root canal treatment, post and core
  - root submergence
  - extraction and/or intentional replantation
- these options are in part dependant on the patient's age, cooperation and relevant clinical findings. It would not be unreasonable to ask for a second opinion from a local restorative dentistry department before definitive treatment

Follow up

- clinical and radiographic review at one week, six to eight weeks, three months, six months, and at one year. Then yearly for five years
- aiming for continued root formation, preservation of pulp vitality and preservation of periodontal attachment

Scenario 6. Complicated crown–root fracture: a fracture affecting enamel, dentine, cementum and pulp

Management

If fragment is in situ:

- in an emergency the fractured coronal portion can be splinted to the adjacent teeth
- assess the restorability and likelihood of being able to complete appropriate vital pulp therapy (Figure 9)
  - supragingival fracture – coronal fragment removal and suitable direct or indirect restoration dependent on restorability assessment of the remaining tooth tissue. As for a crown–root fracture, rebonding of the fragment can be considered if haemorrhage control is suitable
  - subgingival fracture – coronal fragment removal:

TABLE 8

SUMMARY OF COMPLICATED CROWN–ROOT FRACTURE FINDINGS

Assessment	Findings
Clinical presentation	The patient may be aware of a mobile portion of tooth or the fragment may be missing with severe discomfort to touch
Visual inspection	Assess the extent of the fracture relative to the gingival and alveolar level (Figure 9)
Palpation	Usually no step deformities or tenderness
Mobility	Periodontal ligament attachment will usually cause fragment to remain in situ and mobile
Percussion	Likely to be tender
Occlusion	May be altered if fragment is displaced
Pulp test results	Usually positive, although possibly abnormal in acute phase
Radiographic findings	Loss of coronal tooth tissue with fracture line extending to involve the root surface The extent of fracture may not be fully visualised by a periapical and occlusal radiograph therefore a CBCT could be justified

TABLE 9

SUMMARY OF ROOT FRACTURE FINDINGS

Assessment	Findings
Clinical presentation	Patient may report a mobile tooth or displaced crown that is tender to bite on, particularly in cervical 1/3 fractures
Visual inspection	The injured tooth may look normal (Figure 10) or there may be displacement of the coronal segment, and bleeding from the gingival sulcus
Palpation	Normal – ensure no step deformity to exclude alveolar fracture. A periodontal pocket to the fracture line is a poor prognostic indicator (Figure 11)
Mobility	Likely to have increased mobility of coronal segment if involving the middle or cervical 1/3
Percussion	Likely to be tender especially if cervical third fracture
Occlusion	Abnormal if the crown is displaced
Pulp test results	May be negative in the acute phase
Radiographic findings	The fracture line may be horizontal or oblique and located at the apical, middle or coronal third of the root. Radiolucent line running across the root categorised into apical, mid or coronal thirds best visualised on an occlusal radiograph. If inconclusive a CBCT is indicated

Figure 10: (a) A periapical radiograph of the maxillary right central incisor shows a non-displaced cervical third root fracture; (b) The clinical presentation shows very little signs of injury

Figure 11: A periodontal pocketing associated with a traumatised maxillary right central incisor. This is a poor prognostic indicator for a horizontal root fracture

TABLE 10

SUMMARY OF ALVEOLAR FRACTURE FINDINGS

Assessment	Findings
Clinical presentation	Pain and an altered bite
Visual inspection	Multiple adjacent teeth displaced and possible gingival tear (Figure 12)
Palpation	Step deformity, and tenderness
Mobility	Movement of several teeth in unison
Percussion	Likely
Occlusion	Possibly deranged occlusion with premature contacts
Pulp test results	May not respond in the acute phase
Radiographic findings	Fracture line may be located at any level. If inconclusive an orthopantomogram (OPT) or CBCT is indicated

Figure 12: (a) Dentoalveolar fracture that includes all four mandibular incisors. Note the soft tissue tear and that all four incisors moved in unison; (b) A mandibular occlusal radiograph of the incisors shows a faint radiolucent horizontal line in the apical third of the roots; (c) A coronal slice of a CBCT shows that the buccal and lingual cortical plate around the mandibular incisors is fractured

    - gingivectomy with possible ostectomy
    - orthodontic extrusion
    - surgical extrusion
    - root canal treatment, post and core
    - root submergence
    - extraction and/or intentional replantation
  - these options are in part dependant on the patients age, cooperation and relevant clinical findings. It would not be unreasonable to ask for a second opinion from a local restorative dentistry department before definitive treatment

Follow up

- clinical and radiographic review at one week, six to eight weeks, three months, six months, one year and annually for five years
- aiming for continued root formation and preservation of pulp vitality and periodontal attachment

Scenario 7. Root fracture: a fracture of the root dentine, pulp and cementum

Management

Management will be determined by the extent of crown displacement and apico-coronal location of the root fracture.

- if required, reposition the mobile segment of the tooth and confirm the position with a radiograph
- cervical third:
  - apply a flexible splint for up to four months
  - in a mature patient consideration should be given to rigid splinting of cervical 1/3 fractures as stabilisation unlikely unless a degree of ankylosis is achieved[18]
- mid and apical root third:
  - apply a flexible splint for four weeks

Following cervical fractures, the pulp has the capacity to heal, therefore no coronal fragments should be removed and no endodontic treatment initiated in the acute phase.

Follow up

- clinical and radiographic review at
  - four weeks (splint removal for mid and apical third fractures), six to eight weeks, four months (splint removal for cervical third fractures), six months, and one year. Then yearly for five years
  - splinting times are a guideline. If, when the splint is removed, the coronal fragment is still overly mobile the splint can be reapplied
  - for cervical 1/3 fractures, if there is no evidence of coronal fragment stabilisation or loss of periodontal attachment developing, removal of coronal fragment and assessment of restorability is required
- aiming for positive pulp testing results and hard tissue healing at the fracture. Root canal treatment should not be started solely on the lack of response to pulp testing. If root canal treatment is indicated, it should cease at the fracture line

Scenario 8. Alveolar fracture: a complete fracture from the buccal to lingual/palatal of the alveolar bone

Management

- clean the affected area of debris with saline
- digitally reposition the segment. If this is not possible and the displacement is significant an open reduction by OMFS may be required
- stabilise the segment with a flexible splint for four weeks
- suture any soft tissue lacerations

Follow up

- clinical and radiographic review at:
  - four weeks with splint removal, six to eight weeks, four months, six months, one year, then annually for five years
  - splinting times are a guideline. If, when the splint is removed, the coronal fragment is still overly mobile the splint can be reapplied
- aiming for positive pulp response with hard and soft tissue healing. Root canal treatment should not be started solely on the lack of response to pulp testing

Conclusion

Dental trauma has the potential to present to all general dental practitioners. The timely identification of injuries and management of knowledge is key. From the onset of the TDI, the countdown begins for carrying out a comprehensive assessment and appropriate treatment to ensure the highest chance of preserving pulpal and periodontal health. Follow up is key to collecting longitudinal data that will help early identification of any developing complications.

Patient management can be challenging and will require an empathetic and reassuring approach. There are several secondary care adult dental trauma services across the UK and free online resources – it would be prudent to be familiar with these for advice in such circumstances.

DECLARATION OF CONFLICTING INTERESTS

The authors declare that there is no conflict of interest.

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