

# Emergency assessment and treatment planning for traumatic dental injuries

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## ABSTRACT

Trauma involving the dentoalveolar region is a frequent occurrence which can result in the fracturing and displacement of teeth, crushing and/or fracturing of bone and soft tissue injuries including contusions, abrasions and lacerations. This review describes the assessment of patients with these injuries, not in a didactic sense by repeating excellent already published classifications and treatment options, but by addressing questions that arise during assessment. It covers trauma first aid, examination of the patient, factors that affect treatment planning decisions, and the importance of communicating treatment options and prognosis to traumatized patients.

**Keywords:** Assessment, dental trauma, dentoalveolar, traumatic dental injury, treatment planning.

**Abbreviations and acronyms:** CBCT = cone beam computed tomography; PDL = periodontal ligament; TDI = traumatic dental injury; TMJ = temporomandibular joint.

## INTRODUCTION

On average, one-third of people suffer a traumatic dental injury (TDI) of some kind. Injuries include fracturing of teeth, crushing and/or fracturing of bone, and soft tissue contusions, abrasions and lacerations. Many compounding factors affect the incidence of TDIs within a population.<sup>1–5</sup> Injuries must be assessed carefully as the treatment provided immediately after injury has a major influence on prognosis.<sup>6</sup>

For the most part, treatment can be accomplished without too much difficulty provided an accurate assessment is made and established guidelines are followed.<sup>7–9</sup>

Unfortunately, prompt and proper treatment is also not always carried out due to an inadequate knowledge of assessment and treatment protocols, and as emergency care is often provided by non-dental people rather than by trained health care professionals and carers.<sup>10–16</sup> Compounding this is that many patients present to emergency departments and/or to dental and medical practitioners as unscheduled emergencies. Proper assessment is sometimes difficult due to time constraints. Mistakes frequently occur when assessment is not carried out adequately before treatment is instituted. Poor treatment protocols can have very unsatisfactory outcomes for both patients and practitioners.

There are numerous textbooks<sup>17–19</sup> and excellent review articles that discuss the management of TDIs.<sup>20</sup> Most provide comprehensive classifications and describe treatment protocols for individual injury types. This review does not repeat this excellent material. Rather it concentrates on the actual assessment of injured patients, not in a didactic sense, but by discussing questions that need to be addressed during the process. It covers trauma first aid, the examination of the patient, factors that affect treatment planning decisions, and the importance of communicating treatment options and prognosis to patients.

## Assessing the traumatized patient

### What is TDI first aid?

Any collision between the face and almost any object can result in a TDI. While many injuries do not need immediate treatment, most patients do present as emergencies in dental or medical offices, or at accident and emergency departments. TDIs are real dental emergencies. Most patients are upset, children may be crying, they may be bleeding from soft tissues, teeth may be fractured, displaced or lost, plus the patients, parents and guardians are usually traumatized and

anxious for the child in their charge. Adult patients may be anxious regarding the outcome of their injuries and/or angry that the injury has occurred. There may also be legal issues and issues of consent that have to be considered. The psychological effects of an injury to the face, including a TDI, are profound and must be recognized. Patients need to be treated tactfully and with positive reassurance.

Patients who are in pain, distressed, or who are bleeding require immediate attention. After a brief medical history including information on tetanus immunization, any bleeding should be controlled and blood washed from the face and lips. Immediate treatment, positive reassurance, good anaesthesia, cleansing and debridement of soft tissues, and control of bleeding greatly assist in allaying anxiety and facilitate assessment procedures. Soft tissues can be wiped clean with water or mild detergent. Bleeding from lacerations can usually be controlled by positive pressure. Bleeding from the gingival tissues can be controlled if tissues are repositioned and held in place for a few minutes.

Avulsed teeth can sometimes be replanted without causing too much discomfort. If possible, this should be done as an emergency procedure, after the teeth have been briefly rinsed in saline, and then held in place until facilities are available for more definitive treatment, and after an accurate history and radiographic examination is conducted. A bleeding socket is by far the best storage media. If immediate stabilization is not possible, teeth can be temporarily stabilized with a sling suture around the crown. If this is impractical or not possible, teeth should be cleaned and immediately placed in milk or saline solution until time is available for replantation and splinting.

At the same time, it is important not to ignore the examination of the patient as a whole and not be distracted by the presenting dentoalveolar injuries. Immediately after local emergency treatment is carried out and bleeding controlled, and before an assessment of the dentition is carried out, a detailed examination of the patient and the orofacial region must be carried out to rule out any real medical emergencies.

### ***What is a real emergency?***

Real emergencies are where there are medical issues that are more important than the presenting dental problems. These include head injuries, neck injuries, shock and aspiration of teeth or tooth fragments. From a patient perspective, all dental injuries are emergencies and in an ideal world, all should be treated immediately. However, treatment takes time and some definitive treatment is often better if not rushed. Therefore, it is important to identify what are real emergencies and those that can be stabilized and treated with the luxury of time.

### ***Has your patient suffered any head or other serious injuries?***

Immediately after emergency aid is carried out, and during history taking, it is essential to assess whether serious injuries, including neck and head injuries, have occurred. At the same time, vital signs including levels of arousal and headaches should be monitored and recorded, and referral arranged for medical treatment if considered appropriate. Questions that assist in determining the need for referral include:

- (1) Does the patient remember the accident?
- (2) Was there a period of unconsciousness?
- (3) Does the patient have, or has the patient had, a headache since the accident?
- (4) Is there a headache that is worsening over time?
- (5) Has there been any nausea or vomiting?
- (6) Has there been a noticeable behaviour change, e.g. irritability?
- (7) Is the patient confused or drowsy?
- (8) Is there any blurring of vision or limited eye movement?
- (9) Are the pupils of equal size?
- (10) Is the speech slurred?
- (11) Is the breathing pattern irregular?
- (12) Is there any fluid leak from the ears or nose?

Positive responses to any of these questions need to be noted and referral made immediately for neurological screening. Treatment for shock must be considered, as well as the possibility of aspiration of teeth or tooth fragments.

It is unlikely that a patient will attend a dental surgery with severe head injuries. However, as part of the assessment, the whole head and neck should be examined and palpated carefully. Standardized questionnaires and examination techniques and standardized documentation are recommended.<sup>21</sup> The face and all bony margins, including the orbit, should be palpated for signs of bone fractures, bruising, swelling and areas of tenderness noted, and the neck palpated and freedom of movement assessed. The temporomandibular joints (TMJs), the maxilla, the mandible and peripheral areas that may be in the zone of the injury should be visually examined and palpated. Bleeding from the ear may be a sign of a condylar fracture. Signs of a neck injury are restriction of mobility and pain on movement and palpation. Tingling and numbness in the fingers may suggest a neck injury. Whiplash injuries, evident by stiffness of the neck, lack of mobility and stiffness in the shoulders, must be identified and the patient referred for appropriate medical assessment and physiotherapy to avoid the possibility of chronic pain problems in the future.

In situations where specialist services are not locally available and/or where patients need transportation for care, consideration must be given to stabilization.

If a neck injury is suspected, provision of a neck brace is advisable. A neck brace is also an effective way of stabilizing most mandibular fractures.

### **What are TDI emergencies?**

Avulsion, lateral and extrusive luxations require immediate treatment,<sup>8,22</sup> as do alveolar fractures and displaced root fractures. Treatment of avulsed teeth is extremely time sensitive and requires prompt management, particularly in the first 15 minutes after trauma. Immediate tooth replantation should always be encouraged but is not always possible as most patients are likely traumatized, distressed, in pain, and bleeding from soft tissues. If this is not possible, all efforts should be made to place the avulsed tooth in a medium able to preserve the periodontal ligament (PDL). Milk remains the most recommended medium.

Uncomplicated crown fractures, tooth concussion and subluxation are not classified as emergencies. While significant pulp problems are unlikely to result if exposed dentine is left untreated within 24 hours, a critical factor in long-term prognosis is the prevention of bacterial penetration into the dentinal tubules.<sup>23–25</sup> Ideally, all exposed dentine should be covered promptly. Patient discomfort due to sensitivity of exposed dentine may also prompt early coverage of dentine. Pulp in teeth with horizontal crown fractures have better prognosis than deep corner fractures, which should be covered as a priority. Fracture reattachment is a viable treatment modality with a good prognosis and provides an excellent functional and aesthetic result. Thus, wherever possible, patients should be instructed to collect and bring teeth and fragments of teeth with them to the dentist.

Prognosis of traumatically exposed anterior teeth by conservative pulp capping and partial or complete pulpotomy procedures is excellent, even with an elapse of time.<sup>26–29</sup> However, most complicated tooth fractures (crown fractures that involve the pulp) should be treated within 24 hours.<sup>23</sup> If tooth fragments are available, they can be stored in saline or water and consideration can be given to their reattachment once conservative pulp therapy has been completed.

Soft tissue injuries also need to be considered a priority. While facial lacerations in healthy individuals heal well compared with other parts of the body,<sup>30</sup> soft tissue lacerations should still be closed expeditiously. Where degloving of the gingiva has occurred, including displacement of interdental papillae, interproximal sutures should always be placed.

The severity of the soft tissue injuries must be assessed and early consideration given to who will be responsible for their management. Specialist care is indicated in deep through and through lesions, especially if

the vermillion border of the lip is involved. If soft tissue laceration requires specialist care, and/or cannot be repaired immediately, damaged tissues can be temporarily repositioned with large sutures and the injuries kept moist until more definitive treatment can be carried out.

Contaminated abrasions must be cleaned of impregnated debris within the first 24 hours to prevent tattooing (Fig. 1). Removal of debris, particularly bitumen (tar), takes time and may involve vigorous brushing of the tissues. With young children a general anaesthetic may be necessary.

### **What records are necessary?**

Details of the accident must be recorded accurately for future reference and for medico-legal reasons. Also, a timeline is essential, allowing decisions to be made regarding the replacement of teeth and establishing a prognosis for other injuries. Records should be made of the circumstances of the injury as well as the objective and subjective findings. Details can be forgotten if this recording is left till later. Photographic recording is essential for documentation, particularly for use in possible insurance and legal claims.

As a bare minimum, the following information is necessary preferably recorded in the patient's own words (adapted from Andreasen *et al.*<sup>17</sup>):

- (1) When did injury occur?
- (2) Where did injury occur?
- (3) How did injury occur?
- (4) Are there legal implications?
- (5) Are there insurance implications?
- (6) Was a third party involved in the accident?

Two other questions need consideration:

*Are the presenting injuries consistent with the reported cause?*

Not all dental injuries happen by accident. Some result from physical abuse, much of which occurs within a home. Abuse is not restricted to children. Domestic violence and elder abuse also occur. Some assaults involve dental injuries. Recognition is difficult. Nevertheless it is important to be aware of signs, which include delay in seeking help, inconsistent reporting and abnormal behavioural responses from partners, parents or caregivers.<sup>17,31,32</sup> Most TDIs occur as a result of a single incident. Therefore, be especially vigilant if a person attends with multiple injuries, the distribution of which is not consistent with a single accident or the description of a reported incident. Take note also if there is a delay in seeking treatment, which raises the suspicion of abuse, particularly if involving a child patient. Sourcing information on previous injuries from other emergency services may provide useful information. While dentists have an obligation by law to report evidence of





**Fig. 1** Spiral CT image (a) and photograph (b) of a patient who suffered a fall from a scooter. Note the gravel (a) (arrowed) still present in the healed wounds and the tattooing of the skin above the eyebrow (b). Some of the gravel removed from the healed wound is shown in (c).

suspected abuse, suspicion may be easier to confirm if the child's general medical practitioner is consulted. They may have suspicions of their own and are often more familiar with reporting mechanisms.

#### *Do you feel safe with your patient?*

Many TDI injuries in young adults are associated with the intake of drugs or alcohol.<sup>32</sup> Therefore, the possibility of patients being under the influence of these must be considered when assessing level of alertness. Also, while a practitioner has a duty of care to treat an injured patient, they do not need to do so for a patient who is intoxicated or under the influence of drugs, and who is threatening, or with whom they do not feel safe. Referral or a delay in treatment is appropriate in these circumstances.<sup>21</sup>

#### *Are there any disturbances or changes in the bite?*

Disturbances in a patient's 'bite' are signs of bone fractures or tooth displacement. Pain on biting related to a displaced tooth is usually easily identified. Obvious disturbances in the bite or a premature contact that cannot be explained by this suggest alveolar or condylar fractures. This requires further radiographic and clinical assessment and/or referral for specialist management.

#### *Can the patient bite together without discomfort?*

A simple test at the initial assessment is to ask a patient if they can bite their teeth together tightly without discomfort. If they are able to, it is highly unlikely that there is a bone fracture present.

#### *Are any of the teeth loose?*

By checking mobility, an assessment can be made of the degree of luxation and the need for splinting. Documentation should include the degree of mobility. Where groups of teeth are mobile, an alveolar fracture is likely to be present.

#### *Are any of the teeth painful to touch?*

Sensitivity to touching can result from stimulation of exposed dentine or pulp, movement of a fractured fragment, or an injury to the supporting tissues. Where soft tissue damage is extensive, or where there are multiple fractured teeth, as happens in severe indirect trauma, patients can be made reasonably comfortable by covering the affected teeth and fragments with a periodontal pack, until soft tissue healing occurs and a detailed assessment of the dentition can be made (Fig. 2). As an emergency procedure a stomatohesive bandage material may also be used to temporarily cover injured teeth and soft tissues until appropriate dental management can be performed (personal communication, Dr Peter Foltyn).

Some teeth that have suffered a concussion injury may be associated with minor alveolar fractures and



**Fig. 2** A patient with severe facial lacerations and severe indirect trauma resulting in shattering of many molar and premolar teeth who has been made comfortable by covering all the broken teeth with periodontal pack for a week, while soft tissue healing progresses.

can remain sensitive to touch for many weeks. Pulp removal will not relieve this symptom. Splinting for 3–5 weeks is usually more helpful. An alveolar fracture should be suspected if pain occurs when adjacent teeth are moved in opposite directions. Alveolar fractures can be confirmed with multi-slice computed tomography or cone beam computed tomography (CBCT) imaging.

### **What about tenderness to percussion?**

Percussion testing is a reliable way to assess damage to supporting tissues.<sup>33</sup> The perceived tactile response to this testing is also important. Teeth that feel ‘soft’ may be mobile and may have been injured. Teeth that give a characteristic ‘ring’ to percussion may be intruded or ankylosed. Teeth that are not sensitive to percussion are unlikely to have suffered a periodontal injury.

Some traumatized teeth can be exquisitely sensitive. Thus, tapping or moving the tooth gently first is recommended before assessing percussion sensitivity using an instrument. Documentation should indicate whether the tooth is not sensitive, slightly sensitive, or very sensitive to percussion.

### **Are any teeth sensitive to hot or cold stimuli or to breathing?**

Sensitivity to air or thermal stimulation immediately after trauma is usually a sign of exposure of dentine or the pulp, or cracking of teeth. Teeth that are sensitive to breathing have live pulps and do not require pulp testing.

### **Were there any previous injuries to the teeth?**

Many patients who suffer a dental injury have had trauma previously.<sup>34</sup> The prognosis is less favourable

for previously injured teeth. Thus, it is important to establish whether teeth have been damaged previously, what injury was sustained, what treatment was carried out and whether clinical and radiographic records can be retrieved for comparison with current recordings. It is also necessary to consider whether tooth structure loss occurred as a result of the current injury, and/or whether it can be attributed to a previous TDI or even displacement of restorations.

### **Have missing teeth or fragments been identified or recovered?**

Patients should be instructed to bring displaced teeth or fragments with them. Replantation of teeth is possible, and fragment re-attachment is a clinically acceptable procedure with a good prognosis. Where fragments or teeth are missing and there are lacerations present, radiographs should be taken with a film positioned between the lip and the alveolus to ensure fragments are not embedded in the soft tissues. Immediate radiographic assessment is also necessary to ensure that ‘missing’ teeth are not completely intruded.

### **How did the injury occur?**

Consideration of the cause of the injury is important. Understanding how the presenting injury occurred can direct assessment and help anticipate complications. TDIs can occur from a myriad of causes. A moving object can damage the dentition or the patient can collide with a stationary object. Trauma can occur directly (*direct trauma*), where the teeth are struck directly by an object. Injury to the dentition is restricted to the area of impact. Depending on the size and composition of the impacting object, trauma may not necessarily be restricted to the teeth that are obviously affected. Assessment and review of adjacent teeth is recommended and necessary. The type of trauma sustained, plus the severity and extent of an injury, are influenced by a number of compounding and co-existing factors. None act independently – the injury is a result of the summative effect of these many interrelated factors. While some of these factors may not be applicable to all injuries, it is important to understand the nature of the injury to understand treatment options and the prognosis. Factors to consider are (adapted from Glendor *et al.*<sup>34,35</sup>):

- (1) the energy of the impact;
- (2) the hardness or softness (resilience) of the object;
- (3) the shape and size of the object;
- (4) the sharpness or bluntness of the object;
- (5) the direction of the blow;
- (6) the size of the face;
- (7) the maturity of the tooth;
- (8) strength and resilience of the supporting bone;
- (9) presence of and protection by soft tissue; and

(10) where the tooth was struck.

Damage can also occur indirectly (*indirect trauma*), where the injury is caused by the forceful impact of mandibular teeth against maxillary teeth. Widespread damage can involve deep fractures and cracking of many posterior teeth, including severe crown and crown-root fractures as well as fracture of the alveolus and condyle. If anterior teeth are involved, crown-root fractures are usually subgingival on the labial. Fractures of the condylar head regularly occur,<sup>36</sup> clinical signs of which include pain over the TMJ, bleeding from the ear, facial asymmetry with deviation on opening, an asymmetric bite with a prematurity on the affected side, a concurrent fracture of the body of the mandible on the opposite side, and hypermobility in lateral excursive movements or a bilateral open bite if both condyles are affected.

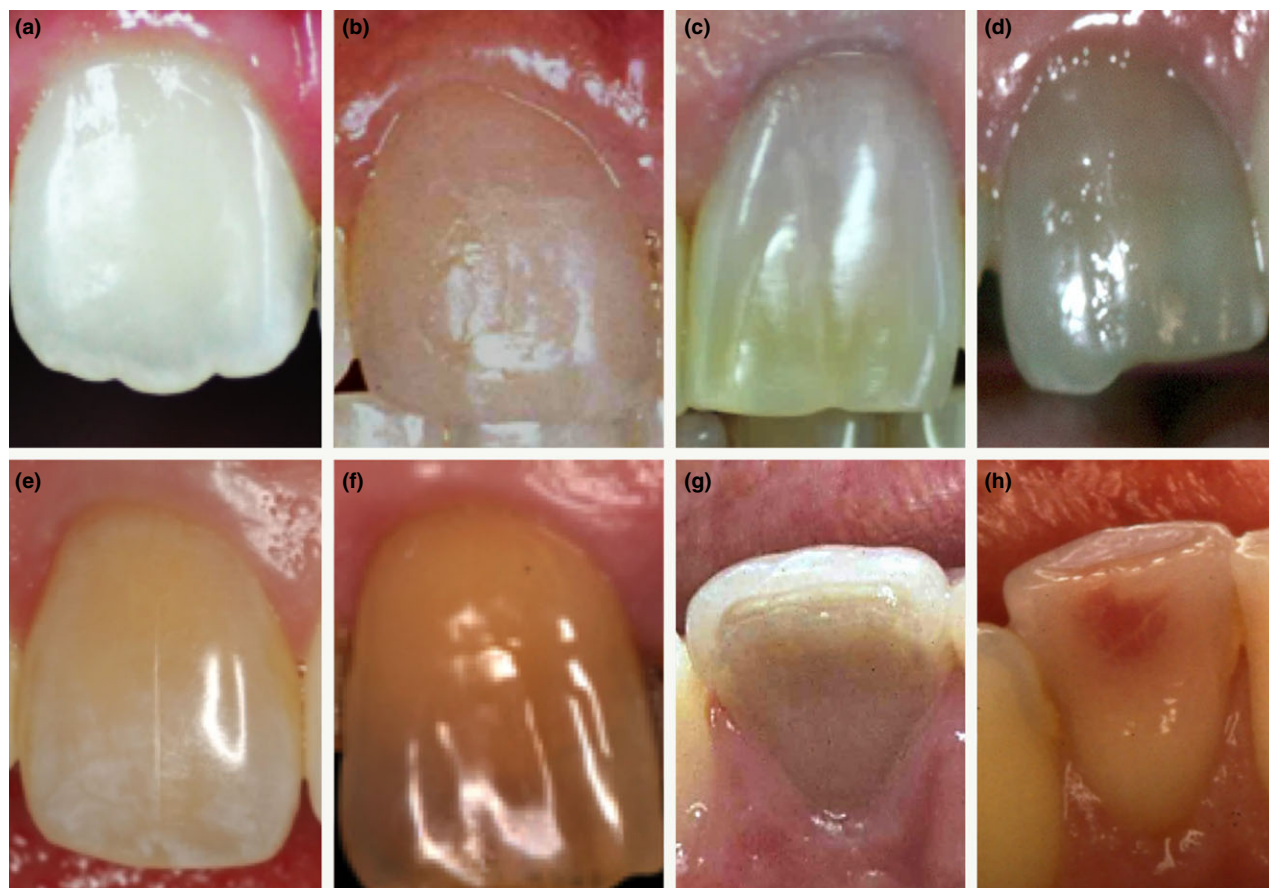
### ***Was contact made with an object or the ground?***

This is especially important when considering the need for tetanus boosters or antibiotic therapy. If a

clean object has caused the TDI, the risk of contamination is considerably less than if the injury has been sustained by contact with the contaminated ground. The environment where the TDI was sustained is thus important, particularly where soft tissue injuries and avulsions are considered. If soft tissues are contaminated, the tetanus status must be assessed and consideration also given to administration of antibiotics.

### ***Has the colour changed?***

Colour changes may occur in traumatized teeth. A pink or purple colour occurs as a result of bleeding into the dentine. In many cases, this resolves over time. A grey discolouration results from breakdown of these pigments and suggests pulp necrosis. A deepening grey or brown discolouration is a sign of pulp necrosis, needing confirmation by pulp sensibility testing. Yellow discolouration is usually a sign of calcification in the pulp chamber (Fig. 3), but this is a longer term effect of trauma.



**Fig. 3** Examples of discolouration of teeth following trauma from various sources. (a) Normal colour. (b) Reddish blush immediately after trauma. (c) Purple colour some months after trauma. These teeth became responsive to pulp sensibility testing and assumed normal colour some years after the trauma. (d) Grey discolouration that is increasing in intensity is a sign of pulp necrosis. (e) Yellowish discolouration is usually a sign of increasing pulp canal calcification within the crown. (f) Brown discolouration is usually a sign of pulp necrosis. (g) Palatal view of a tooth immediately after trauma viewed by transillumination. This tooth became responsive to pulp sensibility testing and the discolouration resolved in a few years. (h) Reddish discolouration due to a resorptive defect. (Photographs courtesy of Drs G Heithersay, B Kahler and E Lauridsen.)



The use of a transilluminating device allows better visualization of tooth colour and translucency as well as identifying enamel cracks or infractions (Fig. 4).

### ***Are any teeth displaced?***

Tooth displacement should also be documented. Patients may report a change in occlusion or report interference in functional and excursive movements. Displacement and/or mobility of teeth may indicate a jaw or root fracture. Radiographic evaluation can assist in identifying changes in tooth position, particularly narrowing or widening (or absence) of the periodontal ligament space. Subtle changes should not be overlooked. These may be more evident with CBCT imaging.

### ***When should pulp sensibility assessment be carried out?***

Pulp sensibility testing should be performed at each appointment in order to determine if an individual tooth response changes over time. As many traumatized teeth do not respond initially to pulp testing, but can do so at a later date, there is an argument to delay pulp testing at the time of trauma. However, it is generally accepted that pulp sensibility testing should be done at the emergency visit to establish a baseline for future testing and follow-up.<sup>37,38</sup> Such initial testing is also a good predictor for long-term prognosis.

Sensibility testing only assesses neural activity and not vascularity; pulps can be vascular (vital) but unresponsive. As blood vessels have the capacity to stretch further than nerves, vascularity can be maintained,

particularly in immature teeth even with movement of several millimetres.<sup>34</sup> However, the further the apex has moved from the surrounding bone, the greater the chance the pulp will become necrotic.

Pulp sensibility testing following trauma is also complicated as erupting and immature teeth respond to testing at a reduced threshold compared with mature teeth. Thus, a diminished response may be physiological.<sup>39,40</sup> The late differentiation of A- $\delta$  nerve fibres in the dental pulp could explain the lack of a reliable and predictable response of erupting and undeveloped teeth to thermal and electrical stimulation.<sup>37</sup> In young patients, the electric pulp test has been shown to be less reliable than CO<sub>2</sub> snow and dichloro-difluoromethane (DDM) or tetra-fluoromethane (TFE) cold sprays, but more reliable than ethyl chloride and ice.<sup>38</sup> Recently, the use of pulse oximetry, which measures blood flow rather than the neural response, has been shown to be a reliable non-invasive and accurate way of confirming the presence of a blood supply (i.e. the true vitality of the pulp).<sup>41,42</sup> Light is passed from a photoelectric diode across the tooth structure into a receptor. Vascularity of the pulp is assessed by measuring changes in absorption of both red and infrared light during a cardiac cycle (Fig. 5).

The unpredictable response of mature teeth to pulp sensibility testing following trauma has been well reported. It is also widely accepted that pulps in traumatized teeth can be in 'shock' for weeks or months. Thus, a negative response to pulp sensibility testing is not conclusive for pulp necrosis in traumatized teeth.<sup>43–46</sup>

With respect to pulp sensibility testing after trauma, three scenarios are possible:

- (1) The pulp may not respond at the time of the initial assessment nor at review appointments. This is not an indication that pulp necrosis has occurred, rather that the tooth be placed under review. Vascularity can be present even in the absence of response to sensibility testing. In the absence of a response to testing, pulp necrosis is only confirmed if the tooth also becomes symptomatic, if there is a change to a grey colour, if lateral root inflammatory resorption or a sinus tract develops, or if there is an enlarging periapical radiolucency.

In rare cases, a periapical radiolucency can develop as an initial sign of healing. Signs of this, termed 'transient apical breakdown', are the development of a small periapical radiolucency associated with resorption into the apical portion of the root canal, which resolves over time. Teeth can show a transient pink or purple discolouration (Fig. 6).<sup>47</sup>

- (2) The second scenario is where a tooth does not respond to early pulp sensibility testing but does

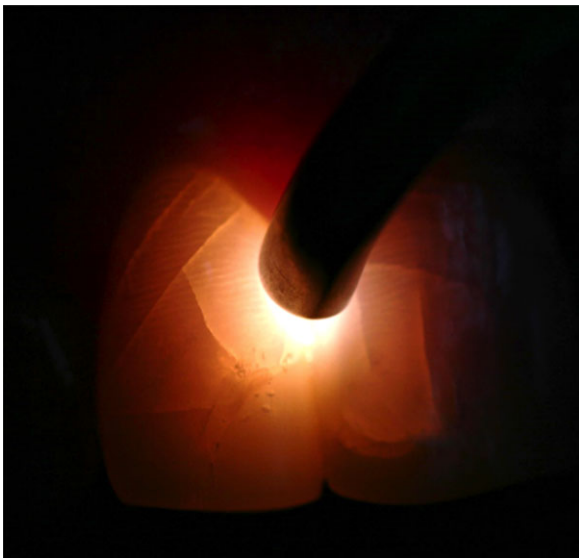


Fig. 4 Severe cracking can be clearly observed on the labial surface of this central incisor by using a transilluminating device.

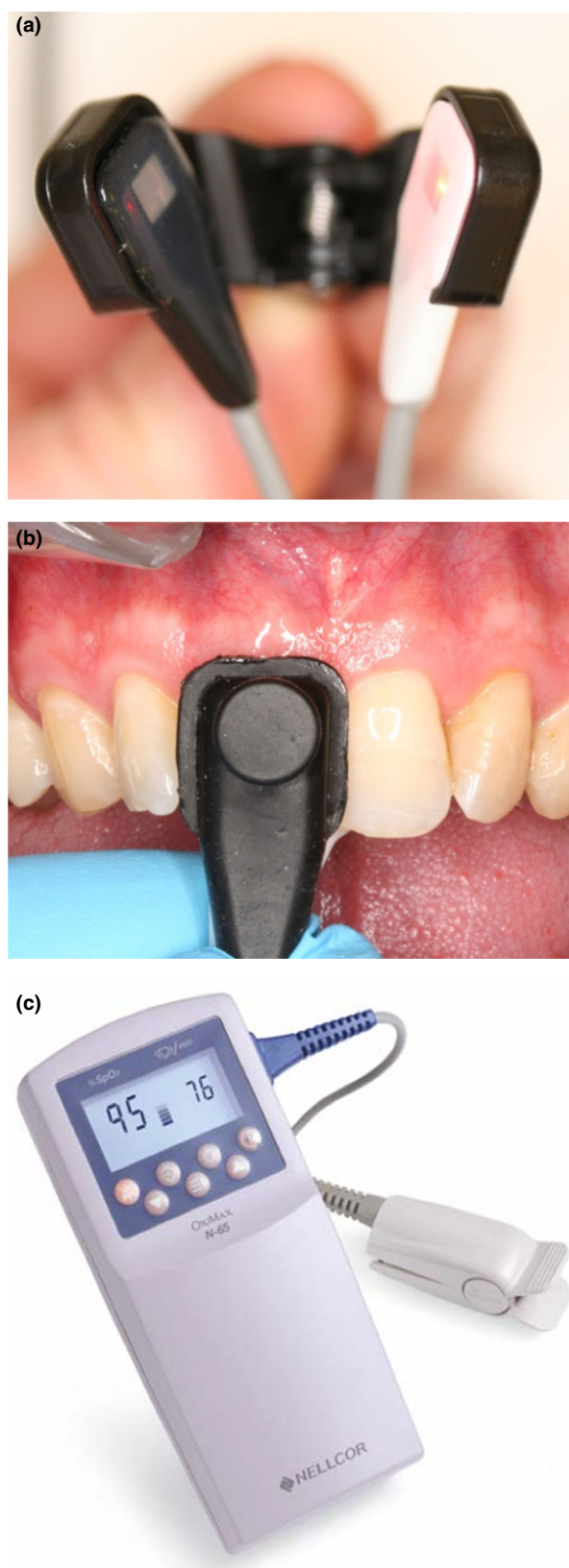


Fig. 5 Pulp oximeter. A view of photoelectric diode and receptor (a). Receptor applied to a central incisor tooth (b). Commercially available pulse oximeter (c) (Nellcor© OxiMax N-65, Nellcor).

respond later (often after 6–8 weeks). This favourable and positive scenario reflects that responses to testing may not be immediately definitive, more so when the tooth has been severely damaged. Pulpas can remain in neurological shock for a number of weeks.<sup>48</sup>

- (3) The third scenario is where a tooth responds positively to pulp testing at initial assessment but fails to respond on review. This negative and unfavourable scenario usually indicates that pulp necrosis has occurred, but this should be confirmed by further testing and other clinical examination findings.

### ***What about calcific changes?***

Of particular importance is to look for calcific changes and ongoing pulp canal changes that occur over time within the root canal in all traumatized teeth. Calcific changes in the pulp or continued root growth are signs of a viable pulp, even in the absence of positive responses to testing. Most calcified teeth will respond to the electric pulp testing devices, but many do not respond to cold tests. Even in the absence of positive signs of pulp sensibility though, if calcific changes are observed within the pulp chamber, and/or if narrowing of root canal space occurs, the pulp is alive and functioning (Fig. 7). Completed root development has been found to be related to pulp revascularization.<sup>21,49</sup> If further root development is not observed when compared to a contralateral tooth, it is possible that the pulp has become necrotic (Fig. 8).

### ***What radiographs should be taken?***

Intraoral radiography is still recommended for the initial screening of TDIs. Radiographic assessment should be done during the initial appointment, not only for accurate diagnosis, but also to establish a *baseline for comparison* later. Guidelines published by the International Association for Dental Traumatology (IADT) suggest that several intraoral radiographs should be taken at different angles as well as an occlusal film.<sup>7</sup> As radiographic comparisons need to be made at reviews, care should be taken to ensure that radiographs are taken in a reproducible manner to allow valid comparisons to be made later. Radiographs used at follow-up may indicate calcific changes or ongoing tooth development confirming pulp health, or lack of standard developmental changes suggesting degeneration/necrosis.

More extensive radiographic examination involving special views are indicated with extensive injuries. A panoramic film (e.g. an OPG) is a good screening film if alveolar condylar fractures are suspected, and is essential if there is reported pain or stiffness on move-





**Fig. 6** Follow-up of central incisors teeth after trauma. (a) One month after trauma. Note the development of radiolucencies over the apices of both incisors. Both teeth responded positively to the pulse oximeter but not to a cold test. (b) Seven months after trauma. Note the presence of apical remodelling on both central incisor teeth. Photographs taken at the time of injury (c), at one month (d) and at 7 months (e). Note the gradual resolution of the colour changes, particularly on the left central incisor.

ment of the jaw, or where a patient has fallen forward onto the chin with sufficient force to break the skin on the chin. Condylar fractures are often associated with these types of injuries.

Due to projectional geometry and superimposition of overlying dental and anatomic structures, plain films often do not provide clear definition of alveolar fractures, minor tooth displacement and root fractures. CBCT may be a useful adjunct. While it may not yet replace plain films as a universal screening tool, CBCT is increasingly being used to overcome the limitations of plain films in the assessment of TDIs.<sup>50,51</sup> Its use is

recommended where insufficient detail is available on plain films and/or where root and alveolar fractures are suspected (Fig. 9). CBCT imaging provides excellent three-dimensional visualization of resorptive defects during follow-up examinations.<sup>52</sup>

### ***What effect has the age of the child on treatment planning?***

#### ***Degree of eruption***

Immature teeth with deep crown fractures can appear to have suffered a severe dental injury. However,

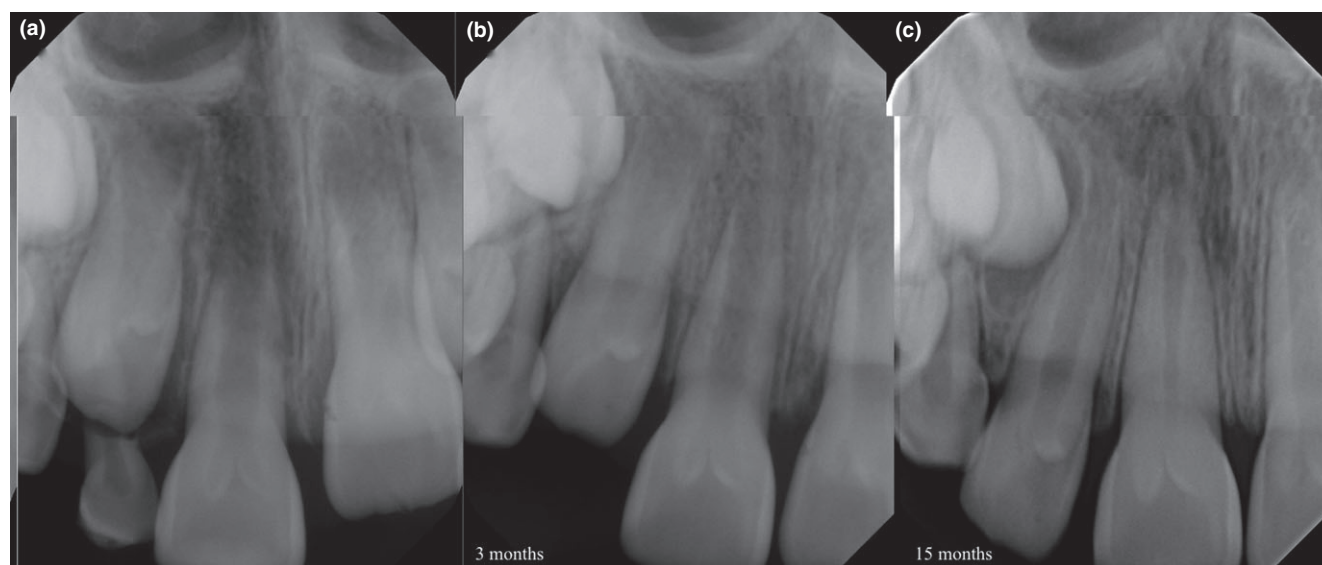


Fig. 7 Radiographs taken immediately after trauma (a), 3 months (b) and 15 months (c) follow-ups. The upper right central incisor did not respond to pulp sensibility testing but evidence of continued root development indicates pulp revascularization.



Fig. 8 Radiographs taken immediately after trauma (a), and at 6-months follow-up (b). The upper right central incisor did not respond to pulp sensibility testing. The lack of further root development (arrows), compared with the upper left central incisor, may be an indication of pulp necrosis.

what may appear to be a deep subgingival fracture may not be so when teeth have erupted completely. In assessing treatment options for young patients, conservative measures (e.g. re-attachment of subgingival tooth fragments and deep temporary restorations) can

be considered until the teeth erupt and the fractured margins become more accessible.

#### *Stage of root development*

Knowledge of the developmental stages of permanent teeth is essential in trauma assessment since it influences diagnosis, treatment planning and outcomes.<sup>53</sup> A classification proposed by Nolla<sup>53</sup> has been widely used and is particularly useful when considering the treatment of traumatized teeth.<sup>54,55</sup>

Numerous studies over many years have shown that traumatic dental injuries involving immature developing teeth can interrupt the development and maturation of the root.<sup>56,57</sup>

When complications occur, which include the development of periapical pathosis and infection-related (inflammatory) root resorption, long-term survival of immature teeth can be compromised.<sup>58</sup> Conservative treatment measures should be planned to protect the pulp in immature traumatized teeth.<sup>59</sup> Care should also be taken to ensure regular review of traumatized immature teeth. In the early stages, radiographic reviews should be planned for every month, and any evidence of infection-related (inflammatory) root resorption noted and treated immediately. Once it develops in immature teeth, infection-related resorption progresses very quickly and a delay of even a week can result in substantial loss of tooth structure.

#### *Importance of growth spurt*

The age of the patient is of utmost importance when assessing whether teeth should be replanted or not. With longer dry times, ankylosis will develop and immature teeth will be lost. As a child grows, teeth erupt and the height of the alveolus increases. Anky-

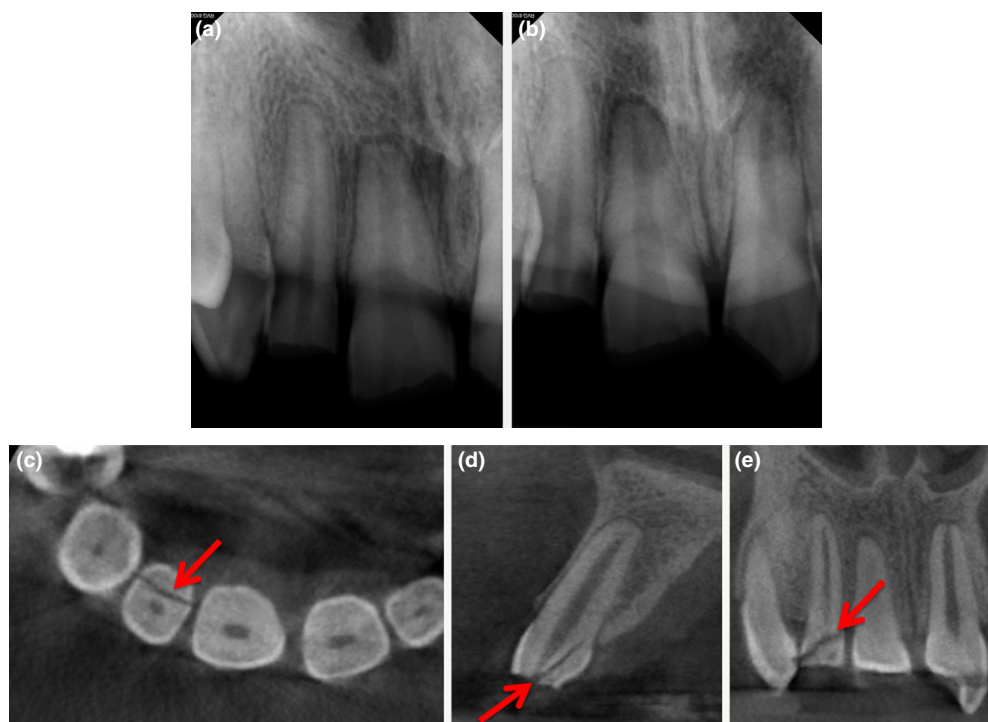


Fig. 9 Radiographs taken to assess the upper central and lateral incisors after trauma. Periapical radiographs (a, b) only show evidence of complicated crown fractures. CBCT images (c, d, e) disclosed the presence and extent of a crown-root fracture (arrows).

losed teeth do not erupt so they become submerged and alveolar growth is retarded. With submergence, the adjacent teeth tip over the submerged tooth resulting in space loss. Therefore, attention should be focused on whether the child has passed through their growth spurt. If they have not, ankylosis and submergence is to be expected. Adjunctive treatment including decoronation and root submergence<sup>60–62</sup> is usually successful,<sup>63</sup> but can be costly and time consuming and should be factored into an initial treatment plan.

With older children and adolescents who have passed through their growth spurt, ankylosis and submergence becomes less of a problem, unless orthodontic treatment is contemplated. In mature patients, as the tooth is usually already in good position, ankylosis is not a major problem. Thus, replantation of mature avulsed teeth with longer extraoral times in an adult dentition can be a more acceptable procedure.

### ***What sort of injury has the patient suffered?***

Each TDI has its own individual complications and treatment priorities. Some injuries constitute real dental emergencies while others do not. Identifying the injury type and understanding the individual management of each type of injury is one of the first goals in the overall management. Being able to diagnose and use the same classification of dental injuries is critical to determine the most appropriate treatment plan.

Injuries can occur to the hard dental tissues and the pulp, to the periodontium, the soft tissues and to the supporting bone. Many classifications have been used to describe these different injury types.<sup>34,64</sup> Andreasen's classification proposed in 1994<sup>65</sup> (Tables 1–4) is the most commonly used.<sup>66</sup>

### ***When should root canal treatment be initiated?***

Many interrelating factors affect pulp survival after trauma. These include: the type of injury, the severity of injury, the age of patient, the size and maturity of the pulp, the maturity of the apex, concurrent soft tissue lacerations and the presence of luxation injuries, the amount of displacement of the apical portion of the tooth away from the apical blood vessels, and the speed of repositioning.

As a general rule, root canal treatment should not be initiated until there is confirmed evidence of pulp necrosis and infection in the root canal. A lack of response to pulp sensibility testing, particularly during the first few months, is not the sole indication to initiate root canal treatment. Other corroborating signs and symptoms are needed. Thus, all teeth with TDIs must be placed on review. The following influence the decision whether or not to initiate root canal treatment:

- (1) Immature teeth generally respond to pulp testing with a reduced threshold compared with mature teeth.



**Table 1. Classification of tooth fractures (adapted from Andreasen<sup>20</sup>)**

	Injury	Definition
Injuries to the hard dental tissues and the pulp	Enamel infraction	An incomplete fracture or crack of the enamel without loss of tooth substance.
	Enamel fracture	A fracture with loss of enamel only.
	Uncomplicated crown fracture	A fracture with loss of enamel and dentine, but not involving the pulp.
	Complicated crown fracture	A fracture involving enamel and dentine, and exposing the pulp.
	Crown–root fracture	A fracture involving enamel, coronal and radicular dentine, and cementum.
	Root fracture	A fracture involving radicular dentine, cementum, and the pulp. Root fractures can be further classified according to displacement of the coronal fragment.

**Table 2. Classification of injuries to the periodontium (adapted from Andreasen<sup>20</sup>)**

	Injury	Definition
Injuries to the periodontium	Concussion	An injury to the tooth-supporting structures without abnormal loosening or displacement of the tooth, but with increased response to percussion.
	Subluxation	An injury to the tooth supporting structures with abnormal loosening, but without displacement of the tooth.
	Extrusive luxation	An injury to the supporting structures with loosening and clinical or radiographic evidence of axial and outward displacement.
	Lateral luxation	An injury to the supporting structures with loosening and clinical or radiographic evidence of lateral displacement. The crown is often displaced palatally and the root buccally. This severe movement is frequently accompanied by fracture of the alveolar socket and buccal plate.
	Intrusive luxation	An injury to the supporting structures with loosening and clinical or radiographic evidence of axial and inward displacement. Tooth is displaced apically into the alveolar bone.
	Avulsion	The complete separation of a tooth from its alveolus by traumatic injury.

**Table 3. Classification of injuries to the soft tissues (adapted from Andreasen<sup>20</sup>)**

	Injury	Definition
Injuries to soft tissue	Laceration of gingiva and/or oral mucosa	Shallow or deep wound in the mucosa resulting from a tear, usually produced by a sharp object.
	Contusion of gingiva and/or oral mucosa	Bruise usually produced by impact with a blunt object and not accompanied by break in the mucosa, usually causing submucosal haemorrhage.
	Abrasion of gingiva and/or oral mucosa	Superficial wound produced by rubbing or scraping of the mucosa leaving a raw, bleeding surface.

**Table 4. Classification of injuries to the supporting bone (adapted from Andreasen<sup>20</sup>)**

	Injury	Definition
Injuries to the supporting bone	Fracture of the alveolar socket wall	A fracture of the alveolar process, which involves the alveolar socket (often correlated with lateral luxation).
	Fracture of the alveolar process	A fracture of the alveolar process that may or may not involve the alveolar socket.
	Fracture of the mandible or maxilla	A fracture involving the body of the maxillary or mandibular process and/or the ramus of the mandible.

- (2) Depending on the time out of the socket, some immature avulsed teeth revascularize after replantation, but constant review is necessary to ensure that infection-related root resorption does not occur.
- (3) All mature avulsed and replanted teeth and mature intruded teeth require root canal treat-

- ment as soon as possible, preferably as part of the emergency treatment.
- (4) Conservative measures, rather than pulp removal should be undertaken to preserve the pulp in an immature traumatized tooth to allow root maturation to occur.

- (5) All immature teeth that show signs of infection-related (inflammatory) root resorption require immediate root canal treatment.
- (6) The presence of a root fracture is not an indication to initiate root canal treatment. The decision to initiate treatment in root-fractured teeth is made on review and only in the presence of other signs including bone loss at the fracture site, increasing discolouration, and/or the presence of a draining sinus.
  - Root canal treatment in root-fractured teeth should only be carried out to the level of the fracture.
  - Tooth resorption at the fracture site is not a sign of pulp necrosis in root-fractured teeth.
  - Pulp in teeth with root fractures and luxation of the coronal fragment are more likely to become necrotic.
- (7) Compromised endodontic management is sometimes necessary to hold a tooth in place until a patient stops growing and more definitive treatment can be performed.

#### ***What factors influence the retention of replanted teeth?***

The following factors need to be assessed when considering treatment protocols and prognosis for avulsed teeth: extraoral time, transportation and storage medium (milk or other media), splinting type and time, root surface preparation, socket preparation, endodontic treatment (timing) and antibiotic therapy.<sup>8</sup>

#### ***Should the tooth be splinted?***

As a general rule, all teeth that have been repositioned require splinting, as do all teeth that are mobile. There are numerous splinting techniques described in the literature. What matters most is that the splints are flexible to allow the physiological movement of teeth, and they should be easy to remove. If available, the use of orthodontic brackets and wire splints have the advantage that small corrections in the occlusion can be made if the teeth are not repositioned exactly in the right position. They also allow the wire to be removed easily and replaced if mobility is an issue. Where multiple injuries occur, splinting time is governed by the major presenting injury. Times are determined by the severity of accompanying bone injuries. Where teeth are displaced without bone fractures, e.g. in most avulsion and extrusive luxation injuries, splinting times are kept to a minimum (1–2 weeks). Where root and alveolar bone fractures occur, splinting times are of the order of 3–5 weeks. Splinting of root-fractured teeth is dependent on the mobility of the fragment and the degree of displacement.

#### ***Should antibiotics be administered?***

Antibiotics significantly decrease the risk of infection to mandibular fractures with oral communication. There are no randomized clinical trials that support the use of antibiotics in the treatment of fractured, luxated and avulsed teeth. Antibiotics in cases of replantation of avulsed teeth are customary to prevent a possible risk of acute infection and inflammatory resorption.<sup>67–70</sup> Amoxicillin is the drug of choice unless there is a history of penicillin sensitivity.

#### ***What are orthodontic considerations?***

When an injury occurs during orthodontic treatment, movement should be delayed or suspended to allow healing. For minor injuries, a period of three months is recommended.<sup>71,72</sup> For more severe injuries involving root fractures, avulsions, intrusions and lateral luxations, a longer period of waiting is recommended (e.g. up to a year). Anecdotally, however, where severe injuries occur and where ankylosis is expected, there is an argument for commencing orthodontic management immediately so that when ankylosis occurs the teeth are in a good position for future orthodontic or restorative care, including the placement of implants. There is also an argument for moving traumatized teeth with poor prognosis into position to maintain the bone of the alveolar crest during the growth of the jaw. Where immature teeth are involved, orthodontic treatment should be delayed until there is evidence of resumption of root development. There is no contraindication to continuing the orthodontic treatment once apexification treatment has been commenced. The orthodontic extrusion of traumatized teeth<sup>73</sup> with crown-root fractures is a proven technique with a good prognosis. With young patients who suffer deep subgingival fractures without pulp exposure, re-cementation of the fragment without first removing it is a viable temporary alternative that can last for many years. Re-attachment of deep crown-root fragments is also possible after endodontic management as a temporary procedure until the patient reaches an age where other restorative procedures can be undertaken.

#### ***What about multiple injuries?***

Most textbooks and trauma guidelines describe treatment for dental injuries on a tooth-by-tooth basis, but many patients present with severe dentoalveolar injuries involving multiple teeth and accompanying soft tissue lacerations. Assessing treatment priorities when confronted with an array of different injuries occurring together is difficult. As a broad generalization, treatment should be skewed towards managing the

worst injuries. Sometimes this is at the expense of textbook recommendations for lesser injuries. In young patients, it is of the utmost importance that the pulp be preserved to ensure continued root growth and development and an intact dentition.

### ***What effect has a TDI on quality of life?***

In recent years the influence of different therapeutic protocols on quality of life has received attention. Such an injury may impact on children's lives directly (dentally) or indirectly (socially). The severity of the injury can have a corresponding negative impact on self-image and social interaction in children and adolescents. Adolescents with more severe untreated TDI are more likely to self-report a higher negative impact on their oral health related quality of life than those without a TDI.<sup>74</sup> Moreover, families of adolescents with severe TDI are more likely to report a negative impact on quality of life, affecting family activities and emotions, which can result in family conflicts.<sup>74</sup> Thus in assessing a TDI, it is important to understand the influence that therapeutic protocols can have on a patient's quality of life, and plan accordingly, e.g. of the different treatment approaches after avulsion, immediate replantation demonstrated the lowest impact on quality of life and it was considered the ideal treatment option for aesthetics, function and psychological impact.<sup>75</sup>

### ***What about prognosis and planning reviews?***

Complications following trauma include pulp necrosis and infection, pulp canal calcification and root resorption. Before treatment is undertaken, an assessment must be made of the prognosis for each injury. This is difficult to assess as every patient, every tooth and every accident is different. Prognosis is not only influenced by the degree and type of trauma, but also by the maturity of the tooth.<sup>76</sup> Additionally, many patients present with multiple and different dentoalveolar injuries. Each injury has a specific pattern of complications, which are as individually unpredictable as each injury and as each tooth is different. Evidence-based literature is limited due to sample size, methodology and classifications. Interpretations differ markedly from study-to-study. Nevertheless, generalizations can be made by viewing historical evidence. It is important to be aware of the average prognosis expected for traumatized teeth so this information can be explained to patients and can be included in reports.<sup>21,77,78</sup> Reference to the Dental Trauma Guide ([www.dentaltraumaguide.org](http://www.dentaltraumaguide.org)) and to the IADT dental trauma guidelines ([www.iadt-dentaltrauma.org](http://www.iadt-dentaltrauma.org)) is helpful.

When composing reports regarding traumatized dentitions, particularly if legal and insurance claims

are involved, it is not only important to describe the type of injury sustained, but also to stress that in some injury types the full scope of injury may not be understood until months or even years after the injury. Resorptive lesions, pulp necrosis with infection and calcifications can develop a long time after an injury. Provision must be made for review appointments.

### ***Who will follow up treatment?***

Before embarking on a complex emergency treatment it is also important to consider what professional help is available to carry out definitive treatment plans and reviews. Every patient deserves the right to the best possible treatment, but practicalities often cloud the issue, and compromise may be necessary. Traumatic injuries are costly and time consuming, and sometimes are perceived to be unprofitable by practitioners. In societies with excellent social networks the problem may not be significant, but this is not always the case. For example, there is no point replanting a tooth with a long dry time in a patient where follow-up help is not available, either due to distance, availability of professional treatment possibilities, or where a patient or guardian is not able to bear the cost of subsequent treatment and reviews.

### ***How do you explain treatment alternatives to the traumatized patient?***

As well as making an accurate record of injuries, and assessing treatment options and priorities, treatment needs must be communicated to the patient and/or guardian if applicable. In simple situations, initial treatment is a relatively easy procedure, but explaining this treatment, the prognosis and expected complications, and the need for reviews is not always so. Injured patients and/or their guardians are often in shock and few remember detailed descriptions of injuries and complex treatment plans. Thus, a written summary should be prepared for them.

A variety of excellent forms and digital recording systems are available to record individual injuries.<sup>18,19,79,80</sup> These recording tools are valuable for research and review, but have little value for communicating with patients and providing them with an understanding of treatment needs, review times and prognosis.

A simple summary communication and treatment planning form is illustrated (Fig. 10). This form, a copy of which a patient can also take with them, contains a diagrammatic representation of the dentition on which the clinician can illustrate the injuries. Space is provided above each tooth for injury description and pulp responses at baseline and follow-up. Treat-



**Treatment planning for traumatized dentition** name \_\_\_\_\_ date \_\_\_\_\_

Prognosis Review						
Treatment Plan						
Pulp						
Injury						

Injury						
Pulp						
Treatment Plan						
Prognosis Review						

**A,B,C**, indicate treatment priorities. **+** and **-** indicate order within the priority group.

**Fig. 10** Summary communication and treatment planning form that can assist in patient communication and prioritizing treatment options. The injury and treatment options are described. Treatment options are prioritized with the letters A (urgent treatment), B (less urgent treatment) and C (treatment that can be delayed). Within each group the priorities are further subdivided into + (plus) and - (minus) options. From this a preliminary plan and appointment schedule can be formulated and provided to the patient.

ment options are listed in the space provided, and the chosen treatment highlighted. Space is provided to indicate plans for review and prognosis.

Once possible treatment options are decided, these can be prioritized with the letters A (urgent treatment), B (less urgent treatment) and C (treatment that can be delayed). Within each group the priorities can be further subdivided into + (plus) and - (minus) options. From this assessment a preliminary plan and appointment schedule can be easily formulated and this can then be discussed with the patient. As with all treatment planning, and particularly with trauma

patients, the plan has to be flexible to allow for developments as time progresses. The patient needs to be forewarned that changes and/or complications can occur over time and what these are likely to be. Consultation with specialist providers may change the treatment or treatment sequence, which can be updated on an existing or new form.

## CONCLUSIONS

Accurate assessment of the traumatic injury before any treatment is essential. For many TDIs, treatment

provided immediately after an injury has a major influence on prognosis. Poor treatment protocols at this time can have very unsatisfactory outcomes for both patients and practitioners. For minor injuries, treatment can be accomplished without too much difficulty, provided an accurate assessment is carried out and established guidelines are followed. Mistakes occur when assessment is not carried out adequately before treatment is instituted. Assessment procedures are often compromised as many patients with TDIs present as unscheduled emergencies. Numerous factors influencing treatment planning decisions must be understood thoroughly so that appropriate treatment decisions can be made, which then must be communicated to the patient who at the time of the accident may not be receptive to descriptions of injury and explanations of treatment options.

## DISCLOSURE

The authors have no conflicts of interest to declare.

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