Traumatic Injuries

15

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Summary

Traumatic dental injuries occur in both young children and adults. Initial emergency management, correct diagnosis, treatment planning and follow-up are essential to ensure a favourable outcome. Treatment procedures are aimed at minimising undesired consequences, which may lead to early loss of the tooth, and also alveolar bone loss, which may have a negative impact on future replacement options. Treatment planning often involves a multidisciplinary approach, and an early endodontic opinion should be sought for the best possible outcome.

Clinical Relevance

Traumatic dental injuries can be classified according to trauma affecting the hard dental tissues, the pulp, the periodontal tissues, the supporting bone, gingivae and oral mucosa. The most favourable outcome of any traumatic dental injury is healing of the pulp and surrounding tissues. The outcome of dental trauma depends on a number of factors including type and severity of injury, timeliness of care and quality of treatment provided. Adherence to trauma guidelines will produce more favourable outcomes, including significantly lower complication rates. Appropriate follow up visits are essential to ensure prompt treatment of complications that can arise several months or even years after the initial injury. The clinician should be aware of types of injuries that can occur and the best possible treatment directed at ensuring optimal healing and retention of the tooth. It is the dentist's professional duty of care to provide appropriate emergency treatment to stabilise the condition prior to making the decision whether to refer to a specialist or not. Good record-keeping is mandatory since a proportion of trauma cases can often lead to legal proceedings for compensation and/or criminal convictions related to the injury sustained.

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15.1 Overview of Traumatic Injuries

The World Health Organization classification of dental trauma modified by Andreasen was first described in 1972 but has since undergone various modifications making a clear distinction between various dental hard tissue and periodontal tissue injuries. It includes injuries to the dental hard tissue, supporting structures, gingiva and oral mucosa allowing anatomical, therapeutic and prognostic considerations to be derived from the classification system [1].

There are eight types of dental hard tissue injuries described dependent on the tooth structures involved and six types of periodontal tissue injuries described dependent on the force and direction of the impact (Table 15.1) [1–3].

The most commonly observed injury to the dental hard tissues involves uncomplicated crown fractures of the maxillary anterior teeth [4]. Crown fractures account for up to 76 % of the dental trauma reported to the permanent dentition. This consists of enamel infraction, enamel fracture, uncomplicated crown fracture, complicated crown fracture and crown-root fractures [4].

Table 15.1 The WHO classification of dental trauma modified by Andreasen

Dental hard tissue injury
Enamel infraction
Enamel fracture
Enamel-dentine fracture (uncomplicated crown fracture)
Enamel-dentine-pulp fracture (complicated crown fracture)
Crown-root fracture without pulp exposure
Crown-root fracture with pulp exposure
Root fracture
Alveolar fracture
Periodontal tissue injury
Concussion
Subluxation
Extrusion luxation (partial avulsion)
Lateral luxation
Intrusion luxation (central dislocation)
Avulsion

Of the periodontal tissue injuries, luxation injuries were consistently found to be the most frequent dental trauma involving the periodontal tissue in studies followed by subluxation. Almost one-third (31.6 %) of teeth suffered a combination of tooth fracture and luxation injury. Furthermore, two-thirds of all combination injuries were observed amongst teeth with minor luxation injuries such as concussion and subluxation [5–8].

The avulsion of permanent teeth is considered to be one of the most serious dental injuries to occur and is seen in 0.5–3 % of all dental traumas. In the worst case scenario the tooth is lost or extracted due to the complications following replantation. The loss of an upper central incisor has a significant effect on dental and facial aesthetics due to the prominence of the maxillary teeth, and this can affect an individual's self-esteem and general social interaction [9, 10].

Infraction injuries are microcracks in the enamel (incomplete enamel fracture without loss of tooth structure). They can be relatively common as a direct result of impact trauma to a tooth requiring no immediate treatment. Pulpal complications are considered to be rare. Pulpal necrosis has been reported in 1.6 % of teeth with enamel infraction and concomitant enamel fracture, whilst 2.3 % of teeth with enamel infraction and concomitant enamel-dentine fracture developed pulpal necrosis. Interestingly, when enamel infraction occurred in isolation, 3.5 % developed necrosis. This has been attributed to the traumatic impact being dissipated through the pulp rather than transfer of energy directly to the supporting tissues resulting in loss of tooth structure. The rate of pulpal necrosis for enamel infraction with a concomitant injury from a concussion or luxation injuries has been shown to range from 14.7 to 60.0 %. Furthermore, the state of root development has been found to be associated with the risk of developing pulpal necrosis (more common in a mature fully developed closed apex teeth). Pulp treatment is rarely indicated and only carried out following definitive signs and symptoms of irreversible pulpitis or pulpal necrosis with infection. The clinician should bear in mind that reactions to pulp sensibility testing in traumatised teeth are lowered immediately following trauma requiring longer observation times before a definitive decision can be made regarding the likely status of the pulp. As with all traumatic injuries, further follow-up after the initial injury is advised [1, 4, 11–14].

Enamel fractures without the exposure of the dentine result in the loss of the enamel structure. The mesial or distal corners of the maxillary central incisor teeth usually sustain this type of injury. Since loss of tooth structure is confined to enamel, patients are asymptomatic not requiring emergency treatment. Pulp survival following enamel fractures has been found to be high (>99 %). However, when there is a concomitant luxation injury, the chances of pulp survival can decrease to 33.3 %. The stage of root development is associated with the potential of pulpal healing following enamel fractures. The risk of pulpal necrosis in teeth that suffered enamel fracture with incomplete root development and open apices was 1.0 % compared to the risk of 2.5 % in teeth with complete root development and closed apices [5–8, 11–15].

When an enamel-dentine fracture without pulpal involvement occurs, the treatment objective is to maintain pulp vitality and restore aesthetics and function. Direct dentine exposure can result in discomfort from temperature changes. Additionally, the enamel-dentine fracture may result in a near pulpal exposure. Emergency treatment prior to definitive restoration includes protection of the exposed dentine. When the fractured crown is retained, bonding and reattachment is considered more aesthetically desirable than the use of tooth-coloured restorative materials. The prognosis of pulpal healing has been reported to range from 94.0 to 100 %. Both extent of dentine exposure and presence of a concomitant injury affecting the periodontal tissues can have an adverse effect on pulp survival. In enamel-dentine fractured teeth with a concomitant luxation injury, 16.8–69.9 % have been reported to develop pulpal necrosis [1, 11–16].

The treatment of the enamel-dentine fracture involving the pulp (complicated crown fracture) is aimed at removing the possibility of bacterial ingress into the pulp, thereby allowing the pulp time to recover and repair. Various treatment modalities including direct pulp capping, partial pulpotomy and pulpectomy have been recommended depending on extent of pulpal exposure and the time elapsed between injury and treatment provided.

In young patients with immature (developing) teeth, it is advantageous to try and maintain pulp vitality by either pulp capping or partial pulpotomy procedures. Pulp capping is indicated when a small exposure is present and can be treated shortly after the dental trauma occurs. When the pulp is more severely exposed and there has been a time delay, then the extent of pulpal inflammation may result in irreversible damage of the superficial layer of the pulp. If an enamel-dentine-pulp fracture occurred, the removal of a minimum of 2 mm of pulp beneath the exposure is required to remove the inflamed pulp. This has given rise to the procedure known as ‘partial pulpotomy’. Alternative levels of pulpal amputation are recommended based on the extent of pulpal inflammation as determined clinically by the presence of pulpal haemorrhage following a dental trauma. In instances where pulpotomy cannot be performed due to the magnitude of pulpal inflammation, pulpectomy is indicated. Following pulpal therapy, the fractured tooth can be restored in a similar manner to an enamel-dentine fracture. The long-term prognosis of the enamel-dentine-pulp-fractured tooth depends on the presence of other concomitant injuries, time elapsed between pulp exposure and treatment, bacterial infection and the stage of root development. Long-term studies of enamel-dentine-pulp fractures treated with partial pulpotomy and using calcium hydroxide showed a success rate of 87.5 % after a follow-up period of 7.5–11 years. The teeth that did not recover required endodontic treatment due to a new injury or for aesthetic purposes [1, 14, 17–20].

Crown-root fractures involve the enamel, dentine and part of the root (cementum) surface of the tooth. The fracture line invariably passes subgingivally often exposing the pulp requiring endodontic therapy if the tooth is to be retained. The treatment of a crown-root fracture is challenging and further complicated by the extent of the subgingival fracture often requiring a multidisciplinary approach. Treatment options include periodontal surgery to expose crown margins, restorative management only with extension of the margins of the restoration below the level of the gingival margin, orthodontic extrusion, intentional replantation (surgical repositioning), autotransplantation, root submergence (decoronation), extraction and replacement or orthodontic space closure. Treatment of crown-root fractures can be complex and time consuming, but often teeth with these types of fractures can be saved. In an adult patient, implant replacement is sometimes a viable alternative. In the case of a growing patient with a tooth that is not restorable, root submergence (decoronation) may be indicated to preserve the bone and allow for normal alveolar development prior to implant placement when growth is complete [21–28].

Root fractures are relatively uncommon, making up 0.5–7.7 % of dental trauma. The maxillary permanent central incisors are most frequently affected (up to 80 % of cases). They involve the cementum, dentine and the pulp and can present with or without clinical signs of luxation of the coronal fragment. The fracture can appear radiographically as a single line or multiple lines across the root in the apical, middle or coronal 1/3. Radiographic diagnosis of root fractures requires multiple views at different vertical angles to obtain a three-dimensional image. Root fractures can occur in either the cervical, middle or apical portion of the tooth.

Many root fractures heal without intervention in one of three modalities: hard tissue interposition, interposition of the bone and periodontal ligament or interposition of the periodontal ligament alone. In the past, rigid splints were used for an extended period of time (up to 4 months); however, no additional benefits were found with regard to pulpal or periodontal healing. The prognosis of root-fractured teeth appears to be multifactorial related to the position of the root fracture, the stage of root development, presence of bacterial infection and the type of healing pattern that occurs. Pulpal necrosis of the coronal fragment has been reported in up to 25 % of teeth with root fractures. Pulp canal obliteration (partial or complete) may occur in up to 70 % of cases. Obliteration of the apical root canal is commonly seen in cases of calcified tissue healing. When interposition of either the connective tissue or the connective tissue and bone occurs between the fragments, obliteration occurs more likely in both apical and coronal fragments. Interestingly, treatment delays showed no significant effect on the frequency and type of healing after accounting for factors such as root development and the extent of displacement. Root-fractured teeth should be splinted for up to 4 weeks initially and then reviewed. In cases where the root fracture has occurred, coronally extended splinting times may be necessary to ensure adequate stabilisation and healing occurs. Follow-up will be required to monitor pulpal status and fracture healing [29–46].

Jaw fractures can involve the base of the mandible or maxilla and often the alveolar process. Tooth involvement is common in mandibular and maxillary fractures and may require additional endodontic management. Nonsurgical treatment of bone fractures involves immobilisation, which for the facial bones is achieved with either maxillomandibular fixation (MMF) using dental fixed arch bars or direct internal fixation using screws and plates. Associated tooth injuries are difficult or impossible to treat during immobilisation, so that some treatment is necessary beforehand (e.g. coverage of exposed dental areas, temporary filling of crown fractures, repositioning of luxated teeth and endodontic treatment if the pulpal vascular supply is lost in the accident). Teeth in the line of a mandibular fracture should not be extracted as a first-aid measure unless they impair repositioning of the jaw fragments [47–54].

Luxation injuries represent the majority of dental trauma in the primary teeth and are the second most common type of injury sustained in the permanent dentition. The extent of injuries to the periodontal tissues is largely determined by the resilience of the underlying periodontal structures. Periodontal injuries often result in displacement of the affected tooth. Treatment of the displaced tooth aims to reduce the amount of dislocation from the tooth socket by repositioning. Common endodontic complications include pulp necrosis with infection, pulp canal calcification, ankylosis and root resorption. Factors that affect the prognosis of luxated teeth include the degree of displacement, delayed treatment time, root maturation and concomitant crown fractures. Most cases of pulp necrosis in luxated teeth become evident with the first 4 months. Root resorption often occurs within the first 6 months after injury and can develop quite rapidly, particularly in immature teeth. Hence, frequent follow-up examination is recommended. In some cases, pulp necrosis may appear at a much later date, and therefore long-term follow-up is also essential.

Concussion and subluxation injuries result from disturbances and/or laceration of the periodontal ligament fibres with very little disturbance to the neurovascular supply. These teeth display little displacement from the bony socket and therefore repositioning and splinting is seldom prescribed. Marked tenderness to percussion but no abnormal loosening or displacement of the traumatised tooth characterises a concussion injury to the supporting structures. Reported frequency of pulpal necrosis ranges from 3 %, and 2–7 % may undergo further pulp canal calcifications. Subluxation injuries are characterised by abnormal loosening of the tooth but without any displacement. Teeth are tender to percussion, and there may be some bleeding in the gingival crevice. Prognosis for subluxation injuries is generally good. Reported frequency of pulp necrosis ranges from 6 to 26 %. Pulp canal calcification has been reported to occur in 9–12 % of cases and progressive root resorption in less than 2 % [1, 6, 55–59].

Extrusive luxation of the tooth presents as a displaced tooth extruded from its socket. Emergency treatment requires repositioning and splinting. A delay in treatment usually results in difficulty in correct repositioning due to an established blood clot. In teeth that suffered an extrusive luxation injury, 26–80 % developed pulpal necrosis. The stage of root development significantly influenced the risk of pulpal necrosis development, with immature roots having a risk of 5.9 % compared with 56.5 % for teeth with complete root development. Root resorption, mainly in the form of inflammatory or surface resorption, was consistently observed in 5.5–9.4 % of extruded teeth [1, 6–8, 60–64, 91].

A lateral luxation injury is associated with a comminution or fracture of the alveolar socket. The tooth may be immobile as the injury crushes the bony socket walls. Emergency treatment for a laterally luxated tooth involves separation of the displaced tooth from the bony lock, repositioning the tooth and then stabilisation for at least 4 weeks. In laterally luxated teeth, the risk of developing pulpal necrosis was found to be between 33 % and 58 % and is related to the stage of root development. When the roots are immature, the risk of developing pulpal necrosis is reported to be 4.7 % compared to the risk of 65.1 % for mature roots. External root resorption is reported in 27 % of laterally luxated teeth and is predominantly surface resorption. The risk of developing inflammatory resorption is relatively low (0.8 %) [1, 5, 7, 8, 63–66, 91].

Intrusive luxation injuries result in a tooth being displaced in an axial position into the alveolar bone. This type of injury results in compression of the periodontal ligament and is accompanied by comminution or fracture of the alveolar socket. The emergency management of an intruded tooth may involve passive repositioning with spontaneous re-eruption or active repositioning with orthodontically guided eruption or surgical repositioning. For intruded teeth with immature root development, spontaneous eruption is preferred. For patients above 17 years of age, active repositioning with surgical or orthodontic intervention is recommended. The type of repositioning depends on the stage of root development and also on the extent of intrusion. For teeth with up to 3 mm of intrusion, passive repositioning is recommended; for 3–7 mm intrusion cases, orthodontic repositioning is preferred; for more than 7 mm of intrusion, surgical intervention is recommended. Of all the periodontal injuries, intrusive luxations are considered to be the most severe due to both the disruption of the vascular supply and the damage to the periodontal ligament cells. Pulpal necrosis is observed in 44–96 % of intruded teeth. Additionally, root resorption is found in up to 80 % of intruded teeth, of which 40 % resulted in replacement resorption [67–73, 91].

Avulsion or exarticulation occurs when a traumatic injury totally displaces a tooth from the socket resulting in potential for periodontal ligament damage and alveolus fracture. Although the prognosis for an avulsed tooth must always be guarded, replantation as soon as possible followed by a brief period of flexible splinting and endodontic therapy has been shown to be the most effective method of treatment. The shortest extra-oral period (less than 15 min), the minimum manipulation of the tooth surface and the socket and the use of an appropriate storage medium (milk, saliva and Hanks' balanced salt solution) have been identified as important factors that minimised subsequent root resorption.

The most common reason for unfavourable long-term survival of avulsed teeth is root resorption. A number of factors have been identified as being important in the prevention and management of root resorption associated with avulsed teeth including the stage of root development, the viability of the periodontal ligament cells and amount of damage sustained, the tooth storage conditions and the duration of time prior to replantation (extra-alveolar drying time).

The best outcome for a tooth avulsion is when the tooth can be replanted within a few minutes after the accident. The prognosis of a replanted avulsed tooth depends on the survival of both the periodontal ligament cells and the pulp. A large percentage of teeth that are replanted within 15 min will result in viable periodontal ligament cells and potential for reattachment within a few weeks. The extra-oral alveolar time has been shown to have detrimental effects on the survival of the periodontal ligament cells (approximately 20 min), and an inadequate storage medium often results in replacement resorption. If an avulsed tooth is left dry for more than 1 h, the odds of periodontal ligament cell survival are very poor. Despite the risk of ankylosis and replacement resorption, it may still be worthwhile replanting the tooth, particularly in a young patient, where several more years of use may be attained before eventual loss of the tooth [1, 10, 74–90].

Transient apical breakdown is a process that can develop as a result of certain traumatic injuries (subluxation, extrusion and lateral luxation) to teeth and their supporting tissues. Radiographically, a periapical radiolucency develops with the affected tooth that resolves without complication and does not require any endodontic intervention. The incidence of transient apical breakdown is relatively low and was reported to be 4.2 % of luxated cases. The condition was associated with either a pronounced radiolucency appearing spontaneously within a short time after injury or with a persistent expansion of the periodontal ligament space progressing over an extended period. During follow-up periods, the radicular and bony conditions either had returned to normal or showed evidence of surface resorption and/or root canal obliteration without further complications [60].

Pulp canal obliteration (calcification of the root canal) is a common sequel following luxation injuries to permanent teeth, particularly teeth that have been injured before their root formation has been completed. Clinically, a yellowish discolouration of the crown may be observed. Pulp canal calcification is also a common occurrence in root-fractured teeth occurring principally in the region of the fracture and in the apical fragment. It may also occur in teeth associated with alveolar and jaw fractures. In most traumatised teeth that have pulps undergoing calcification, the hard tissue is deposited longitudinally along the dentinal walls of the pulp canal. This gradually diminishes the pulp in size until it can barely be observed radiographically. Endodontic treatment is not indicated unless there is evidence of irreversible pulpitis or pulpal necrosis. Pulp necrosis and infection may occur up to 20 years following injury. Assessment of the status of the pulp is difficult since these teeth do not usually respond to thermal pulp sensibility testing. Most, however, do respond to electrical stimulus, and therefore electric pulp sensibility testing is the desirable method for assessing the status of the pulp in calcified teeth [92–94].

Root resorption is a common sequel to dental trauma and may be caused either directly by the traumatic incident or indirectly through subsequent infection. The three most common types of resorption following trauma include surface resorption, replacement root resorption and inflammatory root resorption. Surface resorption is believed to be a self-limiting response to a localised injury to the periodontal ligament or cementum. In traumatised teeth, this type of resorption occurs more commonly in the apical portion of the root and may be seen as a shallow rounding of the external root shape. Replacement root resorption, generally associated with luxated or replanted avulsed teeth, results in the replacement of tooth structure by the bone and can be recognised radiographically by the diffuse nature of the resorption defect and the disappearance of the periodontal space adjacent to the area of the resorption. This progressive type of resorption has a very poor prognosis. Irreversible damage to the periodontal ligament leads to a fusion between the dentine and bone with progressive replacement of the dentine by the bone.

Inflammatory root resorption occurs as a result of a necrotic and infected pulp, which can be recognised radiographically by the development of radiolucency in the bone adjacent to the resorptive defect. Removal of the infected pulp tissue, dressing with an anticlastic medicament and subsequent filling of the root canal with gutta-percha will usually halt the resorptive process [92, 95, 96].

The management of dental traumatic injuries would be incomplete without a discussion of the need to fully assess a patient with dental injuries including dental hard and soft tissues and injuries to supporting tissues and to the patient as a whole. All traumatic dental injuries need to be followed up over time. Follow-up procedures include a clinical examination, a radiographic assessment and pulp sensibility testing [97]. Recommendations for follow-up examinations for injuries are in accord with those recommended by the International Association of Dental Traumatology [1, 14, 15, 20, 27, 44, 51, 58, 60, 63, 73, 90].

Routine radiographic examinations for preoperative, perioperative and postoperative monitoring of complications and healing of dental trauma cases should include a parallel periapical radiograph with the central beam projected through the tooth in question and a lateral angulation from either the mesial or distal aspect of the tooth. The latter allows enhanced visualisation of root fractures that may not be noted when the beam is aimed centrally [98, 99].

Splinting of teeth with luxation injuries, avulsions and root fractures is often necessary to stabilise a tooth in position and to assist in periodontal and pulpal healing. A non-rigid flexible splint has been shown to be the most desirable. An ideal splint should amongst other things be easily fabricated in the mouth without additional trauma; be passive, allow for physiological mobility; be non-irritating to the soft tissues, not interfere with the occlusion; allow endodontic access; and be easily cleaned and easily removed. Recommended splinting times are up to 2 weeks for most avulsion and luxation injuries unless they occur in association with alveolar fractures; up to 4 weeks for lateral luxation injuries, alveolar fractures and root fractures; and up to 4 months for cervical-third root fractures. Many dental injuries do not occur singly. Thus, these splinting times cannot be rigorously applied. In general, splinting times have to be adjusted to accommodate the more major injuries [100–102].

There is limited evidence for the adjunctive use of systemic antibiotics for luxation injuries and no current evidence that antibiotic coverage improves the outcome for root-fractured teeth. The use of intra-canal antibiotics and corticosteroids immediately after replantation appears to halt the progression of inflammatory root resorption, although replacement resorption still occurs to some extent. Antibiotic coverage may be warranted by the patient's medical health and/or injuries sustained, and the decision to provide any coverage lies with the individual practitioner in line with current guidelines [54, 103, 104].

Pulp sensibility testing immediately after trauma is an unreliable means of predicting the true status of the pulp. A negative response is often a common finding immediately after the pulp has suffered trauma. Teeth that initially give a negative response may prove to respond positively in the coming months. Endodontic treatment is only indicated for those teeth in which pulp necrosis has occurred. At least two signs and symptoms (clinical and/or radiographic) are necessary to make the diagnosis of a necrotic pulp. Responses to sensibility testing need to be followed up over time before a definitive diagnosis of pulp necrosis is made [105, 106].

Treatment planning for the management of traumatic injuries should be based on sound biological principles that form the basis of current guidelines. Careful adherence to treatment protocols with these goals in mind should allow for optimal healing and retention of the tooth where possible [107].

15.2 Initial Management and First Aid

Initial management of any trauma should consider the general wellbeing of the patient and any loss of consciousness; acute bleeding, respiratory problems or neurological signs/symptoms may indicate life-threatening conditions requiring urgent medical attention. Often the patient presenting with dental trauma in your office will be stable, showing normalisation of vital functions. The secondary survey starts with the initial history taking and should include general patient details, general medical health of the patient, past tetanus status and questions related to the injury (when, where and how the injury occurred). It is highly pertinent that all information should be obtained in chronological order with contemporaneous notes recorded including time and date of the trauma. This is particularly relevant when an assault is alleged resulting in legal ramifications or insurance matters related to trauma at school or the workplace. It is important for the clinician to calm and reassure the often-distressed patient prior to any initial examination.

Extra-orally simple visual inspection can assess facial symmetry, swelling, facial muscle movements (cranial nerve VII) and mouth opening and deviation (including maximal interincisal distance). Clear draining fluid from either the nose or ears may indicate cerebrospinal fluid, which indicates severe cranial damage. Palpation noting any marked tenderness, bony steps, mobility/crepitus and facial sensation abnormalities (cranial nerve V) can give further clues to any underlying facial bone fractures. Numbness of the lower lip in the context of a facial trauma can be highly suggestive of a mandibular fracture. Numbness of the cheek, nose, upper lip or maxillary teeth may indicate a complex fracture involving the orbitozygomatic complex. Numbness of the maxillary teeth alone may indicate an orbital floor fracture affecting branches of the middle to anterior superior alveolar dental nerve.

Dental injuries can often result in facial or lip lacerations that may require suturing or referral to an appropriate specialist (Figs. 15.1 and 15.2). Before examination of the mouth, a thorough facial examination should have been carried out including assessment of frontal, naso-orbital, nasal, middle-third, zygomatic, orbital and mandibular fractures. Inability to open the mouth, limited opening or deviation may all indicate mandibular or temporomandibular joint fractures. Mandibular fractures will usually be associated with painful, limited opening, and if a condyle is involved, then the jaw may deviate towards the side of the fracture. A deranged occlusion may also indicate a fracture of the mandible or zygoma until proven otherwise. Appropriate referral to an oral maxillofacial surgeon may be required.

Intra-oral examination should include assessment of the crowns of the teeth (checking for signs of possible fracture or pulp exposure), displaced teeth (luxation injuries) and missing teeth, occlusion disturbances and abnormal mobility of individual or groups of teeth and surrounding soft

Fig. 15.1 Clinical photographs demonstrating soft tissue lacerations associated with traumatic injuries. Note: (**a**, **b**) lacerations affecting lips – simple resorbable sutures can be used for primary closure. Deep sutures may be required for muscle repair. (**c**) Laceration affecting the upper lip with vermillion border involvement. Correct suturing will be required to align vermillion border with appropriate skin sutures. (**d**) De-gloving injury affecting the alveolar mucosa. (**e**, **f**) Uncomplicated maxillary central incisor crown fractures embedded in the lower lip (Pictures courtesy of Drs K Dang, A Timmermann, and D Felman)

tissues (including degloving injuries). All missing teeth and fragments should be accounted for (Figs. 15.1 and 15.2).

Radiographic assessment will be invaluable in the diagnosis and management of dental trauma. Extra-oral plain film radiography or cone beam computer tomography is indicated when suspected facial fractures including jaw and condylar fractures are suspected. Soft tissue radiographic assessment is indicated when tooth fragments or foreign objects might have been embedded into the lips. Pretreatment radiographs are essential to determine the size of pulp chamber, the stage of root development and the appearance of the periodontal ligament and presence of any root fractures. Parallel periapical radiographs are also essential to monitor any changes in the pulp space, resorption and calcifications that may indicate future therapeutic intervention.

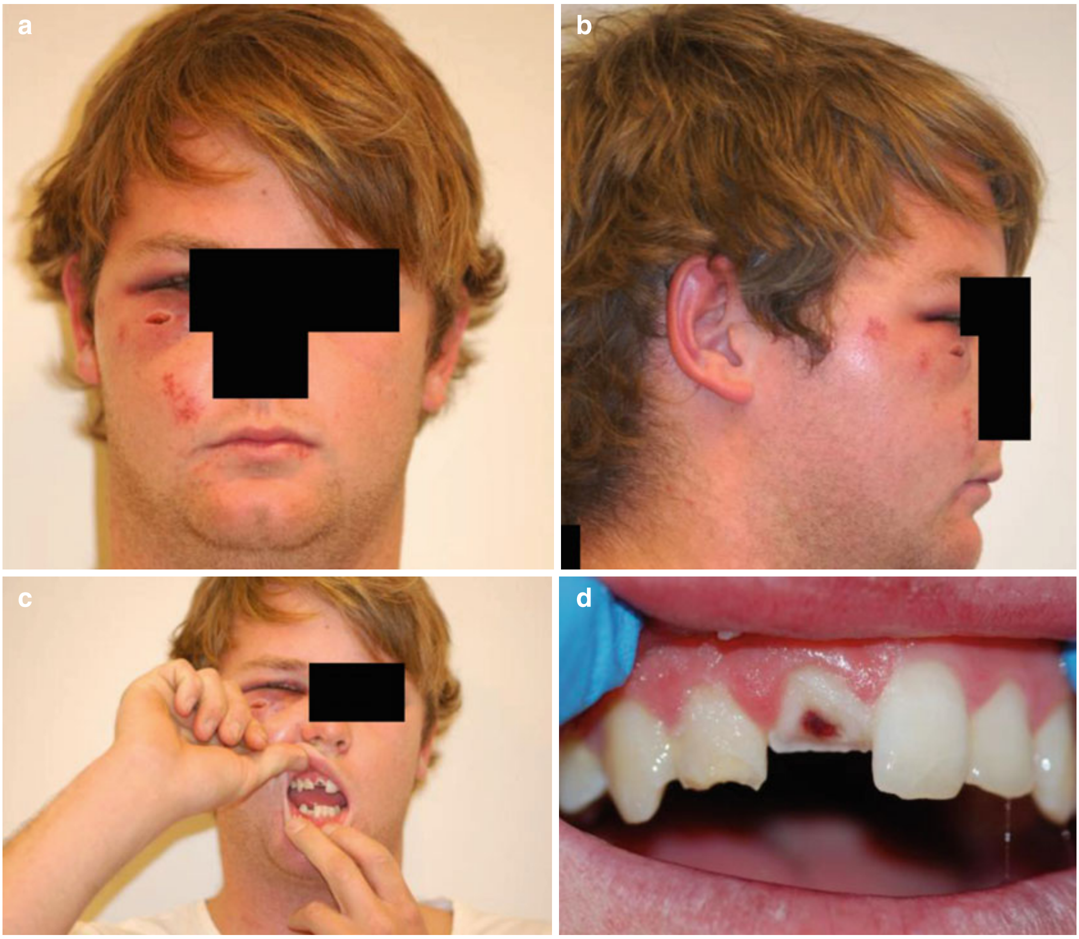

Fig. 15.2 Clinical photographs demonstrating soft tissue lacerations associated with traumatic injuries. Note: (**a**, **b**) facial laceration affecting right infraorbital area with swelling and bruising. (**c**, **d**) Intraoral injury. A complicated crown fracture affecting tooth 11; an uncomplicated crown fracture associated with tooth 12 (Pictures courtesy of Dr K Dang, A Timmermann, and D Felman)

15.3 Crown Fractures

Enamel infraction

Clinical and radiographic findings

An incomplete fracture (crack) of the enamel has occurred without loss of tooth structure (Fig. 15.3). The use of indirect light or transillumination or dyes may help visualise the craze line. Clinical examination reveals no abnormal tenderness to percussion or palpation. Radiographic appearance reveals no abnormalities.

Treatment objectives

Often no treatment is usually indicated. In cases of marked infraction, etching and sealing with a composite resin may prevent future discolouration of the fracture line.

General prognosis

Pulpal complications are rare.

Recommended follow-up

No further follow-up is generally needed.

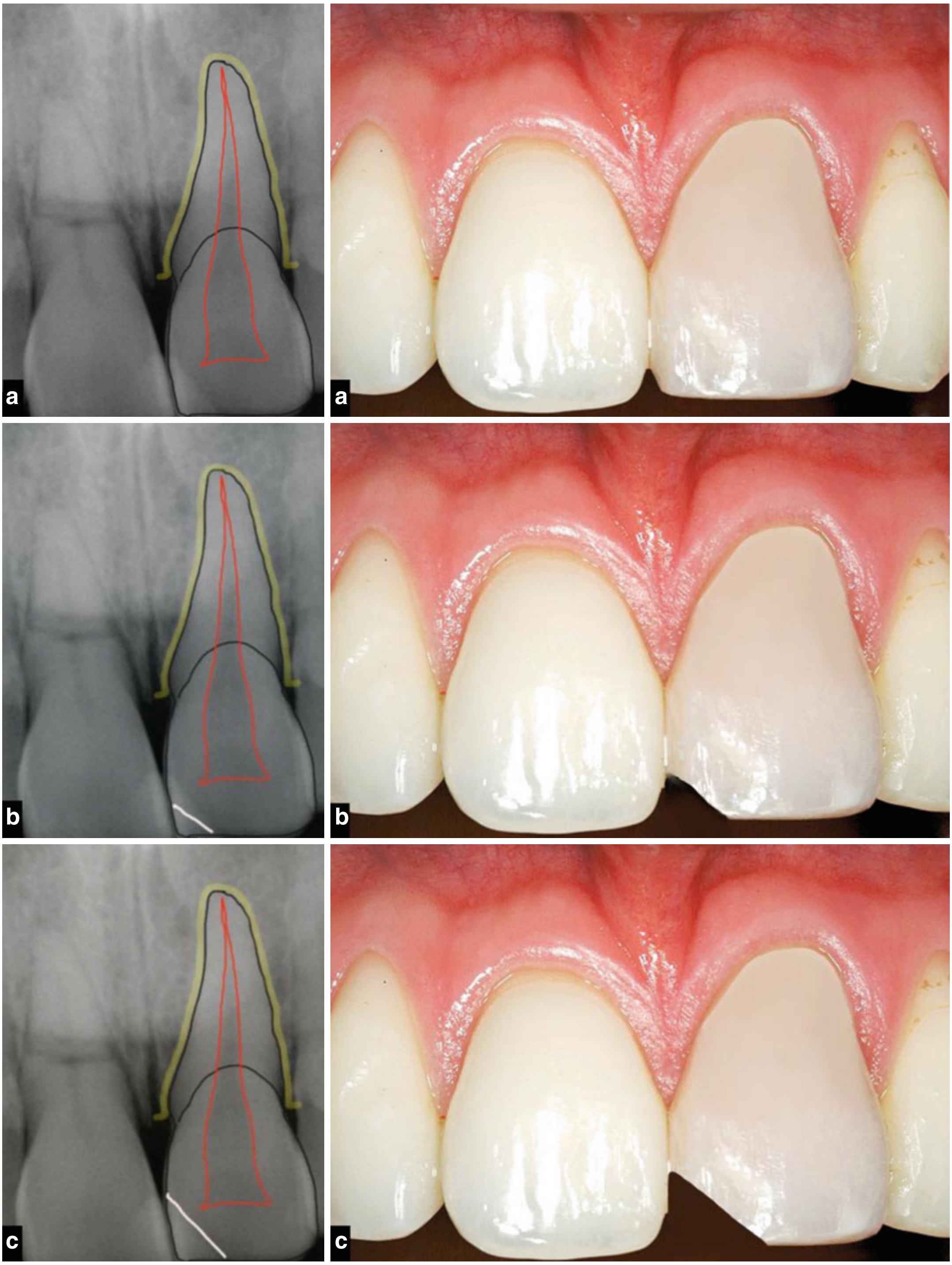

Fig. 15.3 Diagrams representing the different types of crown/root fractures that may present following a traumatic injury. (**a**) Enamel infraction requiring no treatment. (**b**) Uncomplicated crown fracture – enamel only. Reattachment of the tooth fragment or tooth colored restoration will protect the underlying pulp. (**c**) Uncomplicated crown fracture – enamel and dentine. Dentinal tubule exposure can result in sensitivity and pulpal inflammation if left untreated

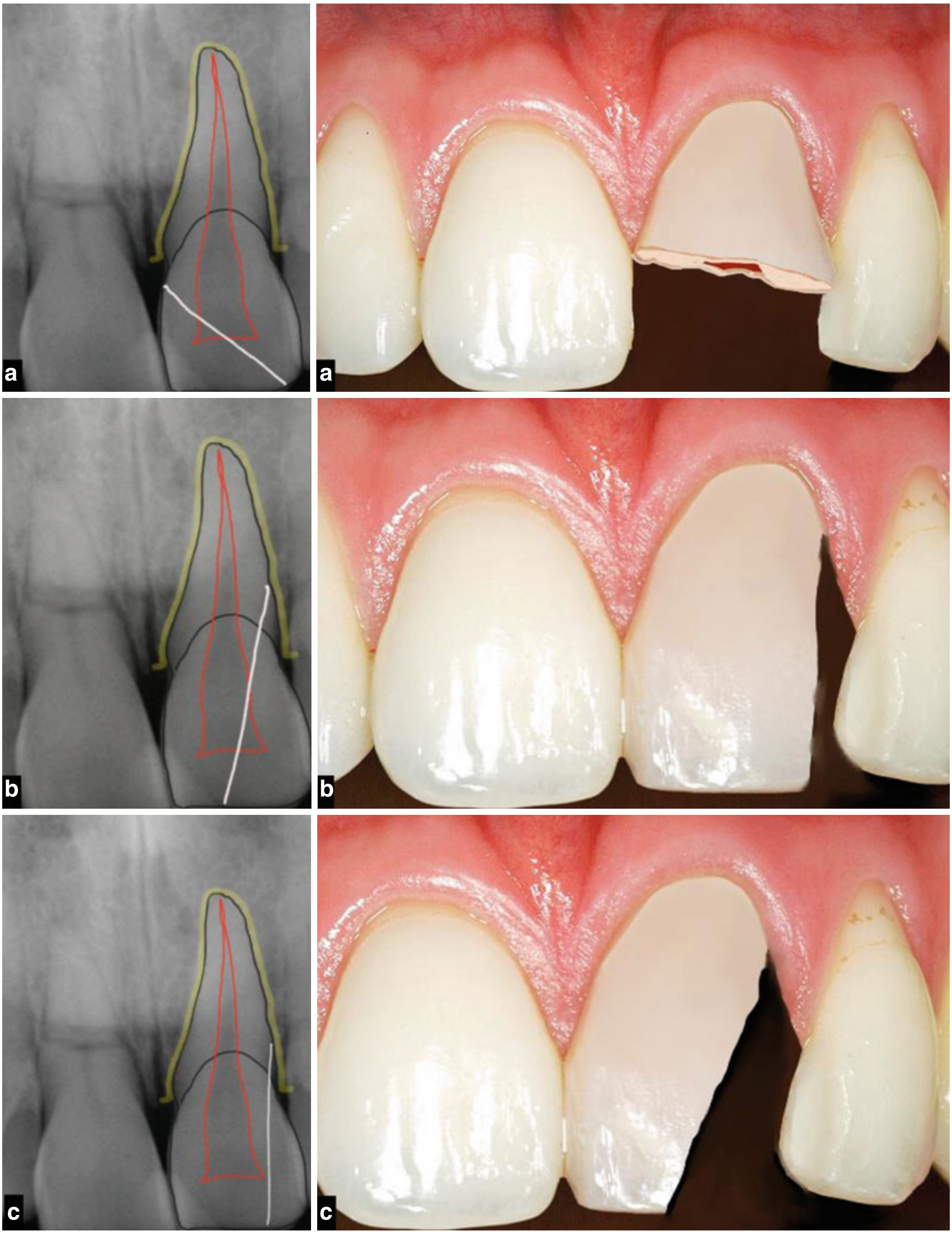

Fig. 15.4 Diagrams representing the different types of crown/root fractures that may present following a traumatic injury. (**a**) Complicated crown fracture – enamel, dentine, and pulp. Treatment options include either pulp preservation procedures (direct pulp capping or Cvek pulpotomy) or pulpectomy procedures. Pulp preservation should be attempted in immature teeth with incomplete root development. Conversely, in mature teeth with extensive loss of tooth structure, root canal therapy is sagacious before cast restoration. (**b**) Complicated crown-root fracture – enamel, dentine, and pulp. (**c**) Uncomplicated crown-root fracture – enamel and dentine only

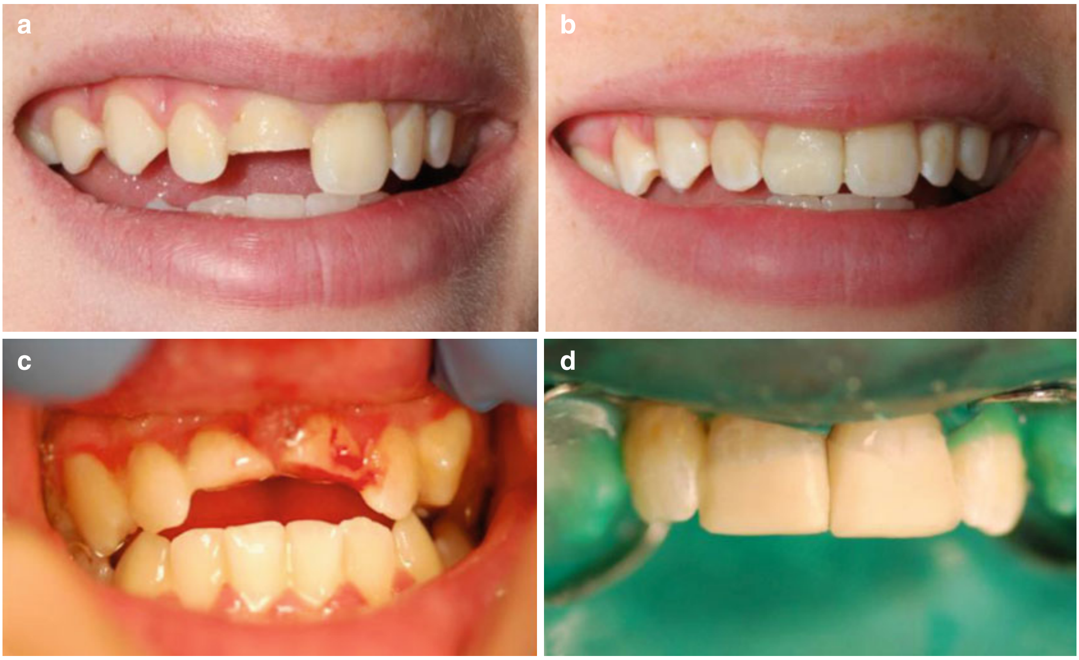

Fig. 15.5 Clinical photographs demonstrating uncomplicated crown fractures. Note (**a**, **b**) uncomplicated crown fracture affecting tooth 11 restored with composite resin restoration. (**c**, **d**) Uncomplicated crown fractures affecting teeth 11 and 21 with appropriate restorations (Pictures courtesy of Drs K Dang and A Timmermann)

Enamel fracture (uncomplicated)

Clinical and radiographic findings

Clinical findings reveal loss of tooth structure confined to enamel (Fig. 15.3). Clinical examination reveals the tooth exhibits no abnormal pain or tenderness. Normal mobility is noted and pulp sensibility testing is normal. Radiographic examination of the soft tissues (lips) may be recommended to rule out the presence of any tooth fragments or foreign material potentially displaced into the lips. Two periapical films should be taken with either a mesial or distal tube shift to rule out the presence of any underlying root fractures.

Treatment objectives

The aim of any proposed treatment is to maintain pulp vitality and restore aesthetics and function. Minor fractures or rough margins/edges should be smoothed. If the tooth fragment is available, then re-bonding may be possible using composite resin and the acid-etch technique. When unavailable, restoration with a composite resin restoration will achieve the desired aesthetic outcome.

General prognosis

Overall prognosis is good although any concomitant periodontal injury sustained can have an adverse affect on outcome.

Recommended follow-up

Due to the unpredictability of dental trauma, pulp vitality testing should be carried out both immediately after the occurrence of the injury and again in 6–8 weeks and 1 year.

Enamel-dentine fracture (uncomplicated)

Clinical and radiographic findings

Crown fractures involving enamel and dentine without pulpal exposure are called uncomplicated crown fractures (Figs. 15.3 and 15.5). Clinical examination reveals loss of tooth structure confined to enamel and dentine with potential exposure of dentinal tubules that can lead to pulpal inflammation. Radiographic examination confirms enamel-dentine loss. Soft tissue radiographic examination of the lips may be indicated to ensure no fragments are present. Presence of root fractures should also be assessed using two parallel periapical radiographs with mesial or distal cone shift technique.

Treatment objectives

The aim is to preserve the vitality of the underlying pulp by sealing the exposed dentinal tubules and restore aesthetics and function for the patient. If the tooth fragment is available, it may be possible to reattach the fragment; otherwise, direct application of dentine bonding agents and the use of bonded tooth-coloured restorations will be effective. Reattachment of the tooth fragment requires isolation of the tooth under rubber dam. Both the tooth fragment and fractured tooth should be cleaned with pumice and water prior to reattachment. Accuracy of fit should be checked prior to the use of acid-etch technique according to manufacturer directions and type of bonding system used. Cases where exposed dentine encroaches to within 0.5 mm of the underlying pulp (determined by visible pink pulp tissue beneath the exposed dentine) will require application of an indirect pulp capping material.

General prognosis

The survival of the pulp and formation of tertiary dentine (reactionary) or pulpal necrosis depend on a number of factors including residual dentine thickness, age of the patient, concomitant periodontal injury and the length of time between trauma and treatment intervention. The overall prognosis for these types of fractures is generally good.

Recommended follow-up

Periodic evaluation is necessary to determine pulpal status and whether pulp necrosis has developed. The patient should be reviewed 6–8 weeks following treatment and at 1 year.

Crown fracture (complicated)

An enamel-dentine fracture with pulp exposure.

Clinical and radiographic findings

Crown fractures involving enamel, dentine and pulp are known as complicated crown fractures (Fig. 15.4 and 15.6). The degree of pulpal involvement can range from a pinpoint exposure to complete coronal pulp exposure. Clinically the exposed pulp may be sensitive to stimuli. Radiographic examination confirms pulpal involvement.

Treatment objectives

Following pulp exposure, bacterial contamination precludes any healing and repair unless the exposure is treated and protected. The initial reaction to pulpal exposure is haemorrhage at the site followed by a superficial inflammatory response. The longer the pulp is exposed before adequate protection, the greater the risk of either destructive (necrosis) or proliferative changes (pulpal polyp). Treatment modalities include direct pulp capping procedures, partial pulpotomy (Cvek), and full pulpotomy or pulpectomy procedures. Vital pulp therapy procedures in young patients with immature developing, thin, weak roots offer the potential for continued root development. Conversely in the fully developed permanent dentition, pulpectomy procedures may offer a better chance of success rather than risking the development of apical periodontitis following direct pulp capping or pulpotomy procedures.

General prognosis

Overall prognosis of attempts to maintain pulp vitality as opposed to complete pulpectomy procedures is dependant on any underlying concomitant periodontal injury sustained, age of the pulp exposure and stage of root development (incomplete versus complete). Treatment modalities aimed at preserving pulp tissue may result in either failure in the future or degenerative pulp changes such as pulpal calcification.

Recommended follow-up

Periodic evaluation both clinically and radiographically should be carried out at 6–8 weeks and 1 year following treatment. Pulp preservation treatments should be assessed for continued pulp vitality ensuring necrosis has not developed.

Crown-root fracture

An enamel, dentine and cementum fracture with or without pulpal exposure.

Clinical and radiographic findings

Enamel, dentine and cementum fracture is present with or without pulpal exposure (Fig. 15.4). The crown fracture will extend below the gingival margin. Clinical examination reveals percussion tenderness. The coronal tooth fragment may be mobile, attached to the gingivae and displaced with or without pulpal exposure. Radiographic examination may reveal a radiolucent oblique line often detected following the use of more than one film using different angulations (horizontal or vertical).

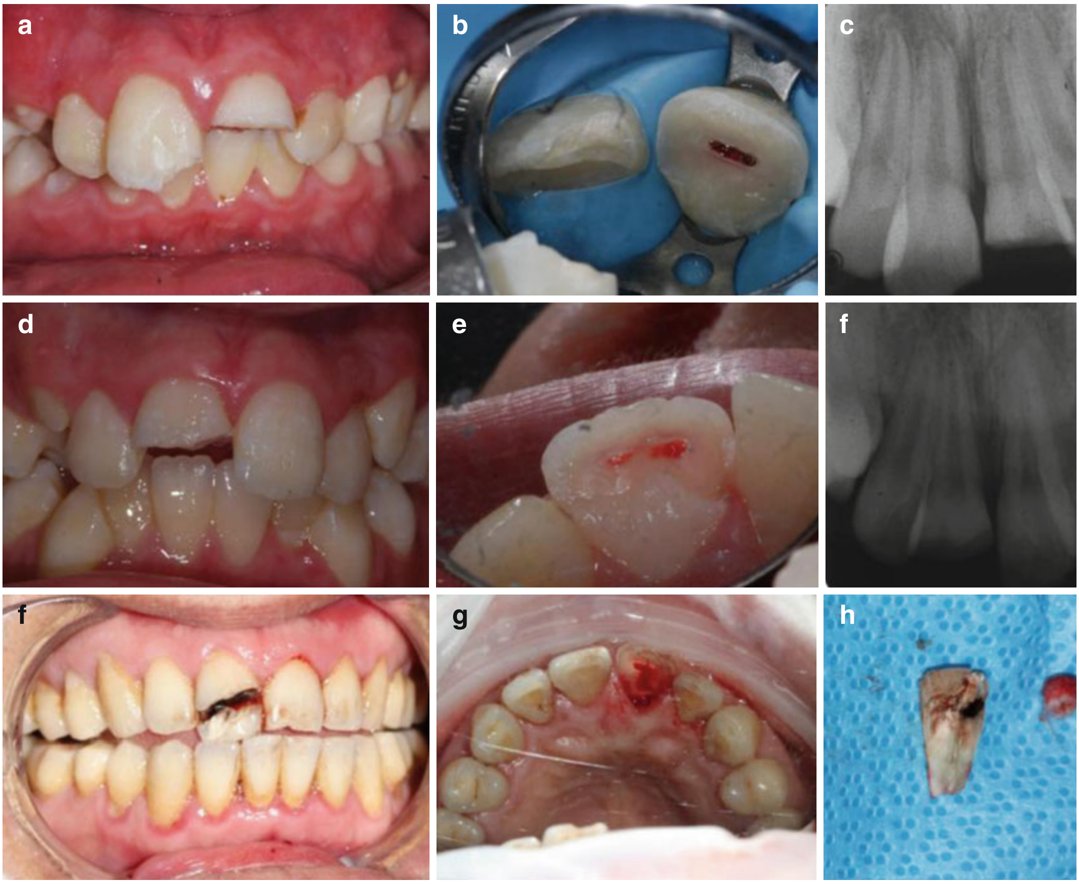

Fig. 15.6 Clinical photographs and radiographs demonstrating complicated crown fractures (enamel-dentine-pulp injuries). Note: (**a–c**) complicated crown fracture affecting tooth 21. (**d–f**) Complicated crown fracture affecting tooth 21. (**f–h**) Complicated crown fracture affecting tooth 21 (Pictures courtesy of Drs K Dang, A Timmermann, and D Felman)

Treatment objectives

Depending on the extent of the fracture, several different treatment options are available. Emergency treatment requires stabilisation of the coronal fragment. Definitive treatment depends on the extent of the fracture. The most conservative approach includes removal of the coronal fragment followed by supragingival restoration. Fragment removal and gingivectomy may be indicated if the fracture extends below the gum. Root canal treatment will often be required prior to further crown lengthening and post and core restoration. Following removal of the fractured coronal fragment and endodontic stabilisation, the apical root may be extruded using either a surgical approach or orthodontics prior to restoration. Sufficient root length must be available after extrusion to support a post-retained crown. If the remaining tooth structure is deemed unrestorable, then either root submergence or extraction and prosthodontics replacement can be carried out. The former is acceptable in cases where implants are planned in the future and alveolar ridge preservation is desirable.

General prognosis

The long-term success in either no pulp or pulp involvement will be dependant on the restorative outcome and ability to maintain a coronal seal. Due to the loss of significant tooth structure and restorability issues, the prognosis is deemed to be guarded.

Recommended follow-up

6–8 weeks and 1 year initially

15.4 Root Fractures

Root fracture

Clinical and radiographic findings

Horizontal or oblique root fractures involving the dentine, cementum and pulp. They can be subclassified according to the location of the fracture line (apical, middle or coronal) (Fig. 15.7).

Clinical findings reveal a mobile coronal segment attached to the gingivae that may be displaced. Bleeding may be evident in the gingival sulcus and the tooth may or may not be tender to percussion. Initial sensibility testing may be negative indicating transient or permanent nerve damage. Monitoring of the pulp status is recommended. Clinically if some time has elapsed since injury and presentation, then transient crown discolouration may be evident (grey/red). Multiple radiographs exposed at different angulations may be required to confirm the presence of a root fracture. Either a horizontal or oblique fracture involving the root of the tooth may be evident with possible separation of root fragments. Often fractures that are in the horizontal plane in the cervical 1/3 can be detected using a regular 90° angle film with the central beam through the tooth. If the plane of the fracture is more oblique (as in apical or middle 1/3 root fractures), then additional film angulations will be necessary to visualise the fracture line.

Treatment objectives

If the coronal fragment is displaced, then it should be repositioned with a non-rigid semi-flexible splint for 4 weeks. Coronal 1/3 fractures may require additional splinting for up to 4 months to allow for healing of the periodontal ligament. If the fracture line is in the apical 1/3 and there is no mobility and the tooth remains asymptomatic, then no treatment will be indicated. Repositioning of fragments should be confirmed radiographically ensuring correct anatomical apposition to allow for optimal healing of both periodontal ligament and neurovascular supply whilst maintaining form, function and aesthetics. If pulpal necrosis develops, then root canal treatment of the coronal segment to the fracture line is indicated (Fig. 15.8).

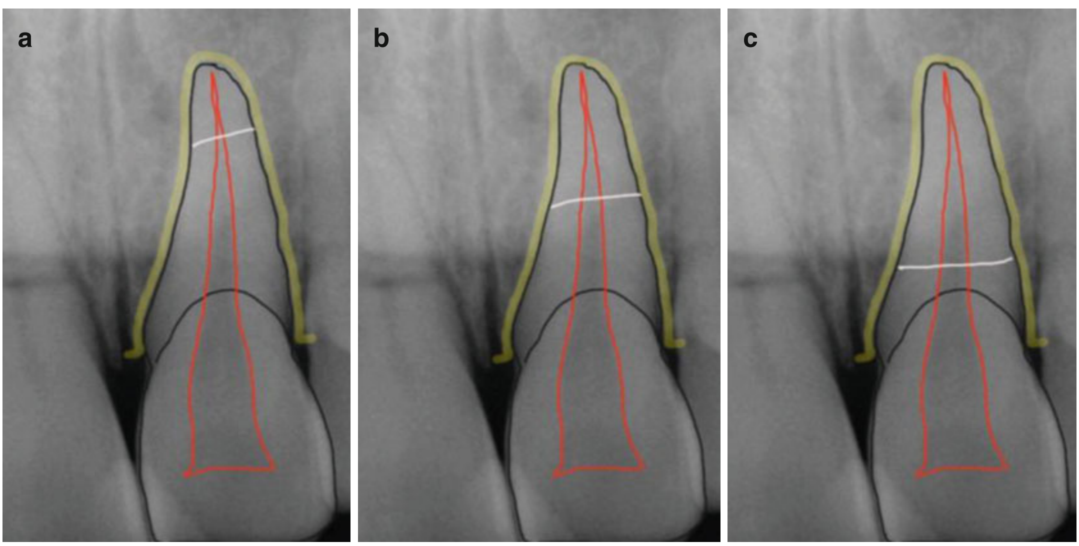

Fig. 15.7 Diagrams representing the different types of root fractures that may present following a traumatic injury. (**a**) Root fracture in the apical 1/3, (**b**) root fracture in the middle 1/3, and (**c**) root fracture in the coronal 1/3

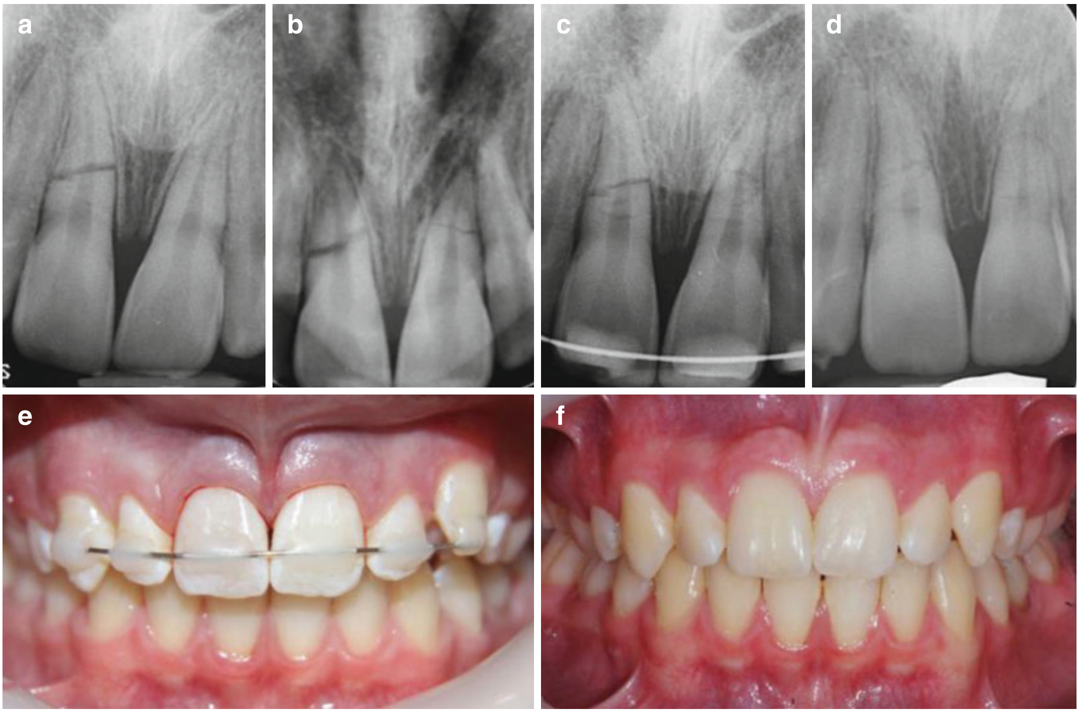

Fig. 15.8 Clinical photographs and radiographs demonstrating middle 1/3 root fracture of tooth 11 and 21 and its management. Note (**a**) preoperative parallel view of the anterior maxillary teeth. Discernible fracture line evident in tooth 11. (**b**) Vertical tube shift revealing additional fracture line in tooth 11. (**c**) Repositioning of fractured segments with a semirigid splint. (**d**) The splint was removed following a period of 2 months. The patient was reviewed a further 6 months later. Note pulp canal obliteration seen in both teeth. Good alignment of the fractures has occurred. Both teeth remain vital responding to thermal stimulus (CO_2 snow) and electric pulp testing. Clinically the teeth were firm with no tenderness to palpation or percussion. The patient was placed on long-term review to monitor pulpal status. (**e**) Clinical photograph of splint in place and (**f**) following splint removal (Pictures courtesy of Drs K Dang and A Timmermann)

General prognosis

Healing of fractures when repositioned occurs by either hard calcified tissue, interposition of connective tissue, interposition of the connective tissue and bone or interposition of granulation tissue. Middle-third fractures are considered to have the best prognosis, whereas fractures located close to the gingival crevice (coronal 1/3) have the poorest outcome. Pulp necrosis in root-fractured teeth is attributed to displacement of the coronal fragment and mature root development. In young patients with immature root formation, positive pulp sensibility testing at the time of injury and approximation of fractured segments to within 1 mm have been found to be advantageous to both pulpal healing and hard tissue repair at the fracture site.

Recommended follow-up

Splinting periods range from 4 weeks to 4 months depending on location of the fracture line. Recommended follow-up should be carried out at 6–8 weeks and 4-month, 6-month and 12-month periods after initial treatment. During the healing period within the first year, the pulpal status should be assessed, bearing in mind that false-negative responses may be possible for up to 3 months. The radiographic appearance of healing of the fracture with hard calcified tissue results in a discernible line with close contact of the fragments. Healing with interproximal connective tissue results in fractured fragments separated by a narrow radiolucent line with rounding of the fracture edges. Healing with interproximal bone and connective tissue results in fragments separated by an obvious bony bridge. No healing with inflammatory interproximal tissue results in a widened fracture line with/without a developing radiolucency.

15.5 Alveolar Process Fractures

Clinical and radiographic findings

Alveolar process fractures are classified as either closed fractures or comminution (crushing or compression) that involves the socket walls (Fig. 15.9). Clinical examination may confirm segment mobility and dislocation with several teeth moving together. A deranged occlusion may be evident. The use of horizontal tube-shift radiographs with an additional panoramic radiograph may be helpful in determining the course and position of the fracture line.

Treatment objectives

The displaced segment should be repositioned to reduce the fracture followed by stabilisation by splinting for 4 weeks. Any gingival lacerations should be sutured. Fracture stabilisation should be carried out as soon as possible to reduce the chance of pulpal necrosis of teeth. Teeth involved in the fracture line should not be routinely extracted since they help in stabilisation (Figs. 15.10 and 15.11).

General prognosis

Teeth involved in the fracture line should be pulp tested and followed up to assess whether vitality is maintained.

Recommended follow-up

Due to the risk of pulp complications associated with teeth in the fracture line, careful follow-up is recommended at 6–8-week and 4-month, 6-month and 12-month periods after initial treatment.

15.6 Luxation Injuries

Tooth luxation injuries from least to most severe are concussion, subluxation, extrusive luxation, lateral luxation and intrusion (Fig. 15.12). With the exception of concussion injuries, luxation injuries frequently result in pulpal necrosis requiring root canal treatment. The fundamental basis of all treatment modalities is to reposition the tooth in the correct position to allow for optimal healing. Prognostic factors for pulpal survival include

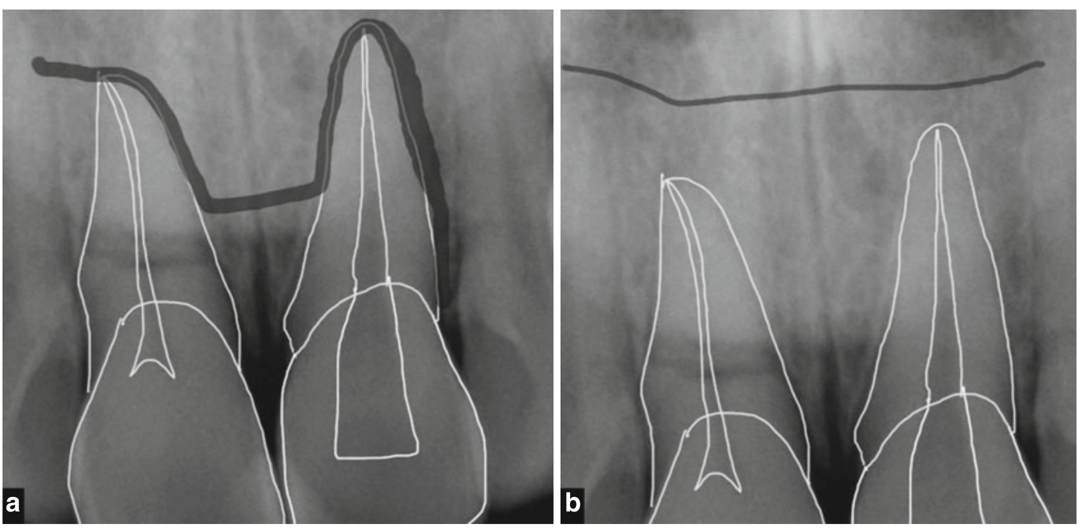

Fig. 15.9 Fracture of the alveolar process; (**a**) or (**b**) may not involve the alveolar socket. Teeth associated with alveolar fractures are characterized by mobility of the alveolar process; several teeth typically will move as a unit when mobility is checked. Occlusal interference is often present

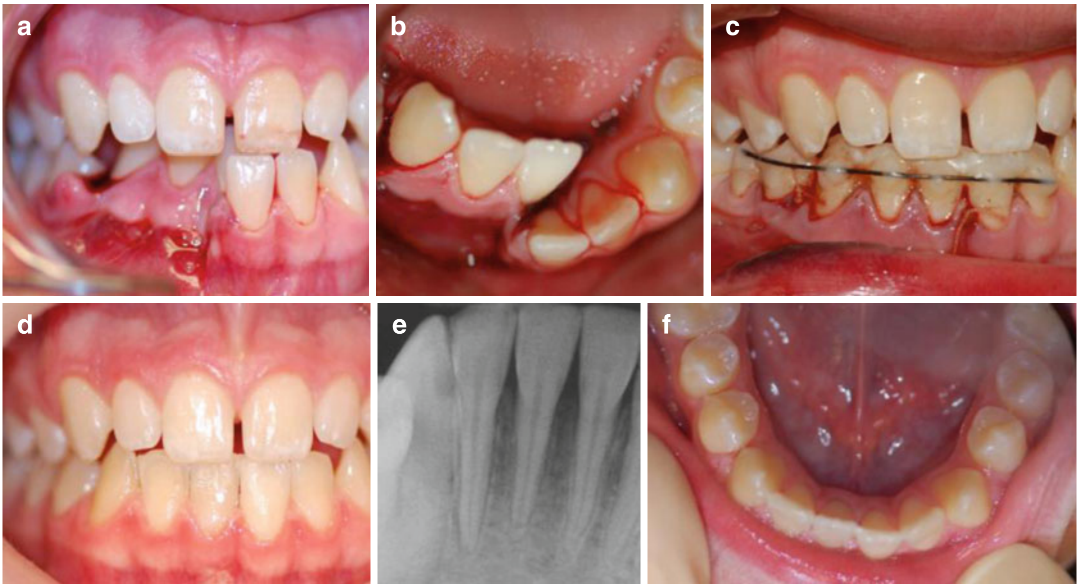

Fig. 15.10 Clinical photographs and radiographs demonstrating dentoalveolar fracture in regions 41, 42, and 43. Note: (**a**, **b**) preoperative views demonstrating deranged occlusion with obvious dentoalveolar fracture. (**c**) Rigid splinting in position. (**d–f**) 4 months have elapsed since splint placement. Occlusion is restored and splint has been removed. Teeth 41, 42, and 43 remain vital with no signs of pulp necrosis (Pictures courtesy of Drs K Dang and A Timmermann)

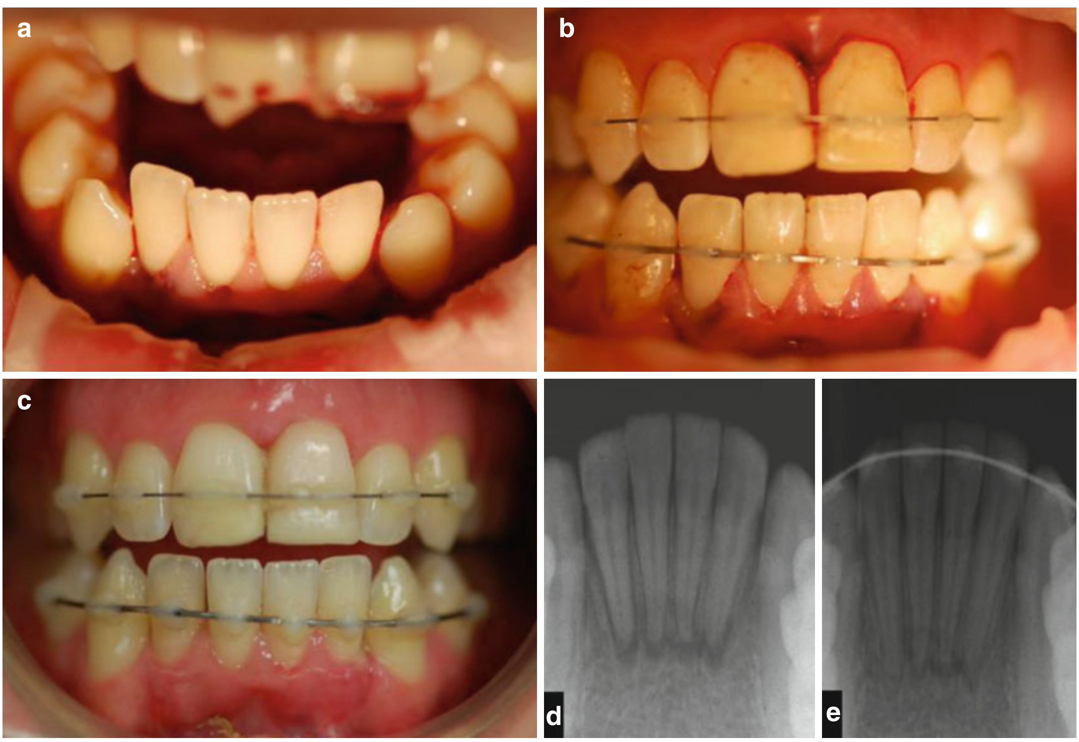

Fig. 15.11 Clinical photographs and radiographs demonstrating dentoalveolar fracture in the lower anterior region extending from 42 to 32. Note: (**a**) preoperative view demonstrating displaced anterior segment with deranged occlusion. (**b**) Rigid splint fixation used to realign lower anterior teeth. (**c**) Splint in position at 3-month review. (**d**) Preoperative lower occlusal radiograph demonstrating periapical appearance due to alveolar segment displacement. (**e**) Following rigid splinting after 3-month interim period. Pulpal sensibility testing using electric pulp testing and thermal stimulus indicate teeth remain vital (Pictures courtesy of Drs K Dang and A Timmermann)

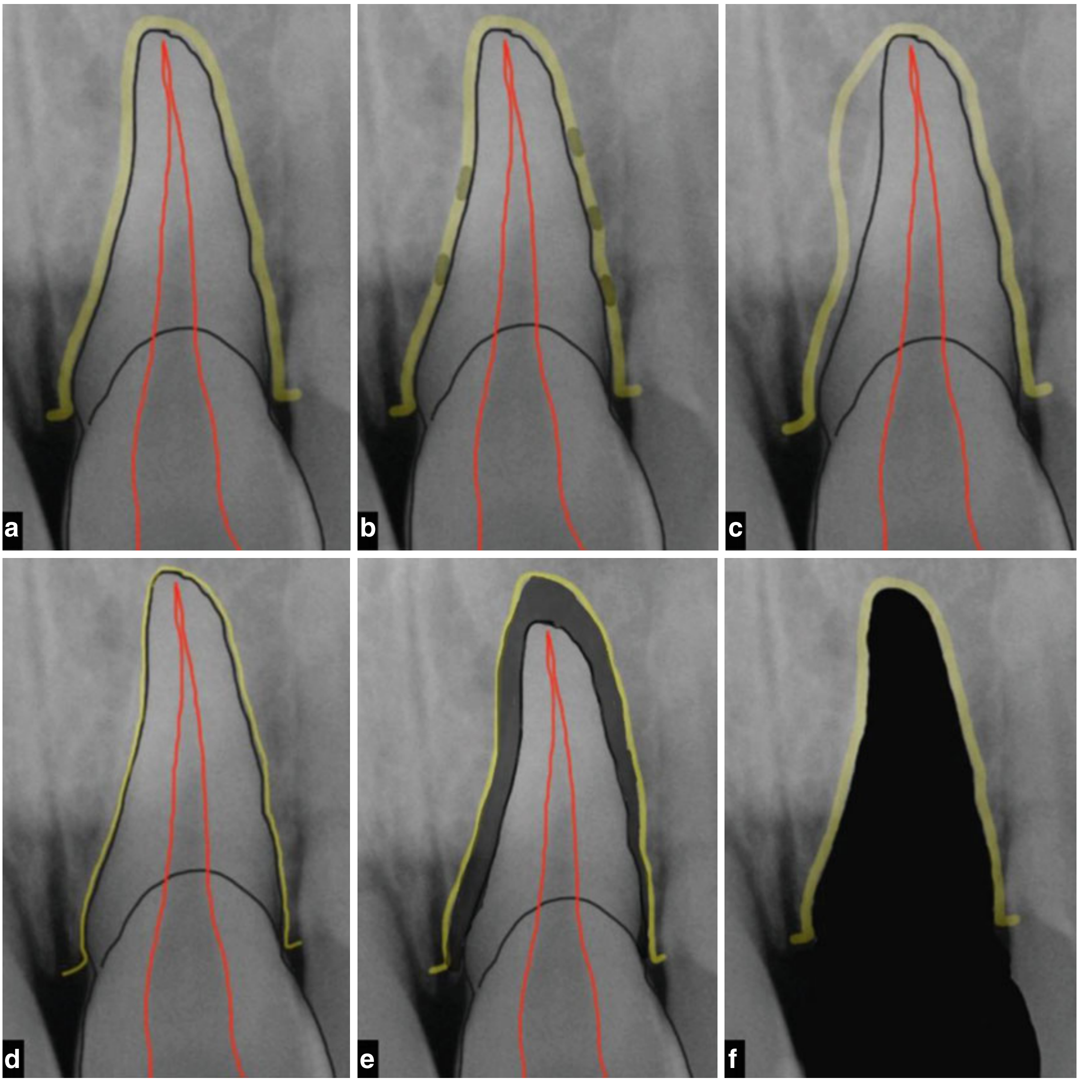

Fig. 15.12 Diagrams representing traumatic dental injuries sustained to the tooth supporting structures (periodontal injury). Note: (**a**) concussion, (**b**) subluxation, (**c**) lateral luxation, (**d**) intrusion, (**e**) extrusion, and (**f**) avulsion

the stage of root development (immature vs. mature) or size of apical foramen (wide open apex vs. closed fully developed), length of the pulp, age of the patient, type of injury sustained, bacterial contamination of the periodontal ligament and pulp and optimal repositioning of displaced teeth.

Trauma and severity related to the type of injury sustained ultimately affect both the blood supply and neurovascular bundle at the apical foramen. Teeth with immature root development with large apical foramina have a greater potential for recovery compared to mature fully developed teeth where pulpal revascularisation (regrowth of new blood vessels and vital cells into the severed pulp) may be limited.

In luxation injuries, stabilisation may be necessary to reposition the tooth in its correct position. This should be done in a gentle manner without excessive forces to ensure further trauma is kept to a minimal and when carried out the sooner after the injury, the better. Current concepts regarding splinting of traumatised teeth (luxation injuries, root fractures and avulsions) are to use a splint that permits some mobility of the injured tooth/teeth. The splint is termed non-rigid and functional which allows for healing of damaged periodontal ligament fibres with less resorption compared to traditional rigid splints of the past. Orthodontic wires bonded to crowns of teeth using composite are sufficient for most cases.

In immature teeth with incomplete root development, the treatment objectives are to promote pulpal healing, revascularisation and continued root development. Initially displaced teeth with pulpal injuries may have temporary ischaemia and subsequent coagulation necrosis, which would account for negative sensibility testing in the first few months. Provided the teeth are protected from bacterial invasion, then the potential for revascularisation and restoration of pulp vitality is possible. Maintenance of pulp vitality for immature teeth is essential for continued root development, and current treatment modalities should be applied to safeguard this concept.

Concussion

Injury to the tooth-supporting structures has occurred without abnormal loosening or displacement of the tooth (Fig. 15.12).

Clinical and radiographic findings

Concussion is the mildest form of injury to the periodontal ligament characterised by sensitivity to percussion only. The periodontal ligament absorbs the injury resulting in inflammation. No abnormal loosening or displacement of the tooth is evident. Pulp sensibility testing will be normal. Radiographic examination reveals no abnormalities. Two baseline radiographs should be taken with different-angled views to rule out the possibility of other injuries to the tooth itself.

Treatment objectives

Concussion injuries do not require any immediate treatment as such. The aim of treatment is to optimise periodontal healing and maintain pulp vitality. The patient is instructed to rest the tooth as much as possible with a soft diet for up to 1 week.

General prognosis

The overall prognosis should be good. Teeth should be monitored for development of pulpal necrosis confirmed by sensibility testing, colour changes and radiographic appearance.

Recommended follow-up

Pulp status should be monitored at 4 weeks, 6 weeks and 12 months following initial presentation.

Subluxation

Clinical and radiographic findings

Injury to the tooth-supporting structures has occurred with abnormal loosening but without any tooth displacement (Fig. 15.12). Pulp sensibility testing should be normal and no radiographic abnormalities should be seen.

Treatment objectives

The treatment objectives are to optimise healing of the periodontal ligament and maintain pulp vitality. Tooth stabilisation with a flexible splint for up to 2 weeks may be required with recommended soft diet for up to 1 week (Fig. 15.13).

General prognosis

General prognosis should be good. There is a greater risk of pulp necrosis in fully developed teeth due to associated injuries at the apex of the tooth.

Recommended follow-up

The patient should be periodically followed up at 4 weeks, 6–8 weeks and 12 months following initial treatment.

Extrusive luxation

Clinical and radiographic findings

Partial displacement of the tooth has occurred axially from the socket (partial avulsion). The periodontal ligament is usually torn. Clinically the tooth will appear elongated with excessive mobility (Figs. 15.12 and 15.14). Pulp sensibility testing is likely to give negative results. Radiographic examination reveals an increased periodontal ligament space apically.

Treatment objectives

To promote healing of the periodontal ligament and neurovascular supply, repositioning of the tooth as soon as possible followed by stabilisation with a flexible splint for up to 2–3 weeks is recommended (Fig. 15.14). In mature teeth with closed apices, the risk of pulpal necrosis is high. Root canal treatment should be considered when signs and symptoms of pulpal necrosis ensue.

General prognosis

In mature teeth with closed apices and complete root development, the risk of pulp necrosis and pulp canal obliteration is high.

Fig. 15.13 Clinical photographs and radiographs demonstrating subluxation injuries. Note: (**a–c**) subluxation associated with tooth 21. Note tell-tell sign of bleeding at the gingival margin indicating subluxation injury. No discernible features usually noted on the radiograph. A semirigid splint is placed for 7–10 days to allow for patient comfort and uneventful healing to take place. (**d**) Subluxation injuries to teeth 21, 11, 12, and 13. (**e**) Post-splint radiograph as a baseline record. (**f**) Semirigid splint placed for 10 days. (**g**) Prior to splint removal. (**h**, **i**) Radiographic and clinical examination at 6 months post trauma (Pictures courtesy of Drs K Dang and A Timmermann)

Recommended follow-up

The patient should be reviewed at 4-week, 6–8-week, 6-month and 12-month periods following initial treatment. Radiographic follow-up will also be required to ensure that external inflammatory root resorption has not occurred.

Lateral luxation

Clinical and radiographic findings

Displacement of the tooth has occurred in a direction other than axially. The periodontal ligament is torn and contusion or fracture of the supporting alveolar bone occurs (Fig. 15.12). Clinically the tooth has been displaced laterally with the crown either in a palatal or buccal direction, and the tooth may be locked in this new position. The tooth may be nonmobile with no tenderness to percussion. A high metallic sound may be evident on percussion testing indicating ankylosis. Alveolar fracture may also be present. Pulp sensibility testing is likely to be negative. Radiographic findings indicate an increase in the periodontal ligament space with displacement of the apex towards or through the labial bone plate.

Treatment objectives

Repositioning of the tooth is desired as soon as possible, and stabilisation of the tooth in its

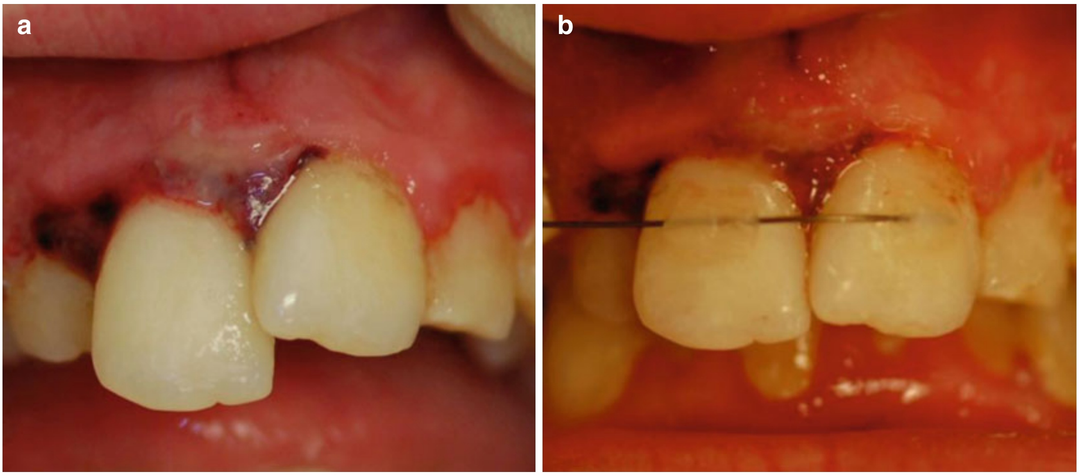

Fig. 15.14 Clinical photographs demonstrating extrusive luxation injury affecting tooth 21. Note: (**a**) preoperative view demonstrating partial extrusion of tooth 21. (**b**) Semirigid splint fixation used to reposition extruded tooth. The splint will be removed at 4–6 weeks, and provided there is no excessive mobility, the tooth will be monitored for signs of pulpal necrosis (Pictures courtesy of Drs K Dang and A Timmermann)

anatomically correct position using a flexible splint for 2–4 weeks is recommended in order to facilitate optimal healing of the periodontal ligament and neurovascular supply whilst maintaining aesthetic and functional integrity. Repositioning should be done with firm digital pressure using minimal excessive forces. Occasionally a displaced tooth may require disimpaction and extrusion to free itself from the apical lock in the cortical bone. The use of forceps to disengage the tooth from the bony lock may be required if digital manipulation is unsuccessful. Pulp status is monitored and root canal treatment commenced if signs and symptoms indicate pulp necrosis (Fig. 15.15).

General prognosis

Common healing complications include pulp necrosis and pulp canal obliteration especially in mature teeth with closed apices and fully developed roots. Development of external inflammatory root resorption or replacement resorption can occur.

Recommended follow-up

Due to pulpal complications, clinical monitoring of pulp status and radiographic follow-up will be required at 4-week, 6–8-week, 6-month and 12-month periods following initial treatment.

Intrusion

Clinical and radiographic findings

Apical displacement of the tooth has occurred into the alveolar bone. The tooth is driven into the socket, compressing the periodontal ligament and commonly causing a crushing fracture of the alveolar socket (Fig. 15.12). Clinical examination revealed the tooth in question may appear shortened or missing. The tooth is often nonmobile and non-tender to percussion. Radiographic findings confirm the tooth has been displaced apically, and the periodontal ligament space does not appear to be continuous. The cement-enamel junction of the intruded tooth will appear to be located more apically when compared to the adjacent non-injured tooth.

Treatment objectives

The tooth should be repositioned in the correct anatomical position followed by stabilisation using a flexible splint for a 2–4-week period. Teeth with incomplete wide-open apices should be allowed to undergo passive repositioning by spontaneous re-eruption. If the intrusion is greater than 7 mm, then either surgical or orthodontic repositioning may be required. Teeth that have undergone complete root development and intrusion of less than

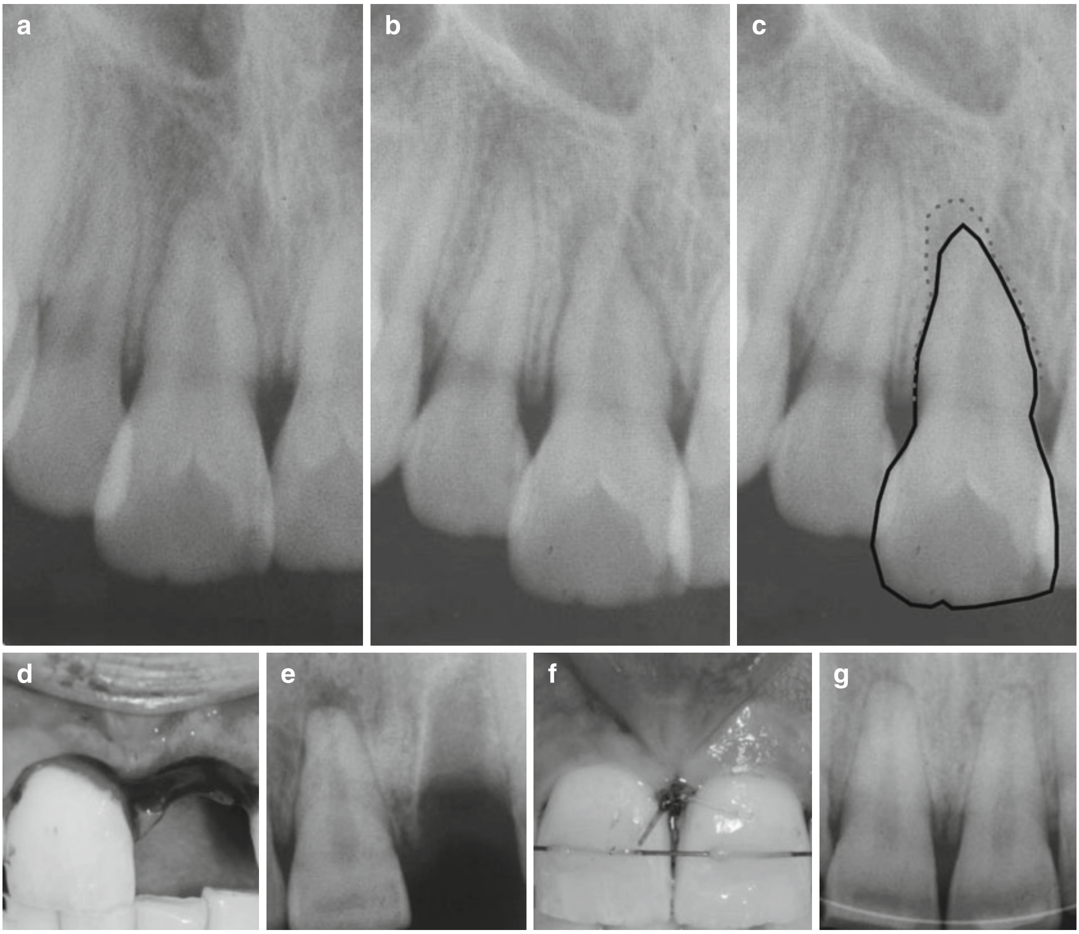

Fig. 15.15 Clinical radiographs demonstrating lateral luxation injury affecting tooth 21. Note: (**a**) long-cone parallel periapical of tooth 21 and (**b**) vertical tube shift to check for any root fractures. (**c**) A peri-radicular radiolucency is evident surrounding the periapex of the tooth confirming a lateral luxation injury. The tooth will need to be ideally manually repositioned. Occasionally the tooth may require surgical repositioning with forceps to disengage the tooth. Complete root development has occurred indicating that the chance of pulp survival is diminished. Follow-up will be required to ascertain whether the pulp survives. (**d**–**g**) Lateral luxation injury to tooth 11 and avulsion injury of tooth 21. Tooth 21 has been replanted and 11 repositioned into correct position prior to semirigid fixation (Pictures courtesy of Drs K Dang and A Timmermann)

3 mm should be allowed to undergo active eruption with no intervention to minimise further pulp and periodontal ligament damage. If no movement has occurred after 2–4 weeks, then orthodontic or surgical repositioning will be required before ankylosis develops. If tooth intrusion is greater than 7 mm, then surgical repositioning will be indicated. After surgical repositioning, the tooth may require additional stabilisation with a flexible splint for a further 4–8 weeks. Mature teeth that have sustained intrusion injuries have a high chance of pulp necrosis developing. In particular, teeth that have undergone surgical repositioning will often require pulpectomy procedures 2–3 weeks after repositioning (Fig. 15.16).

General prognosis

In mature teeth with closed apices and fully developed roots, there is considerable risk of developing pulpal necrosis, pulp canal obliteration and progressive root resorption (external inflammatory and replacement resorption).

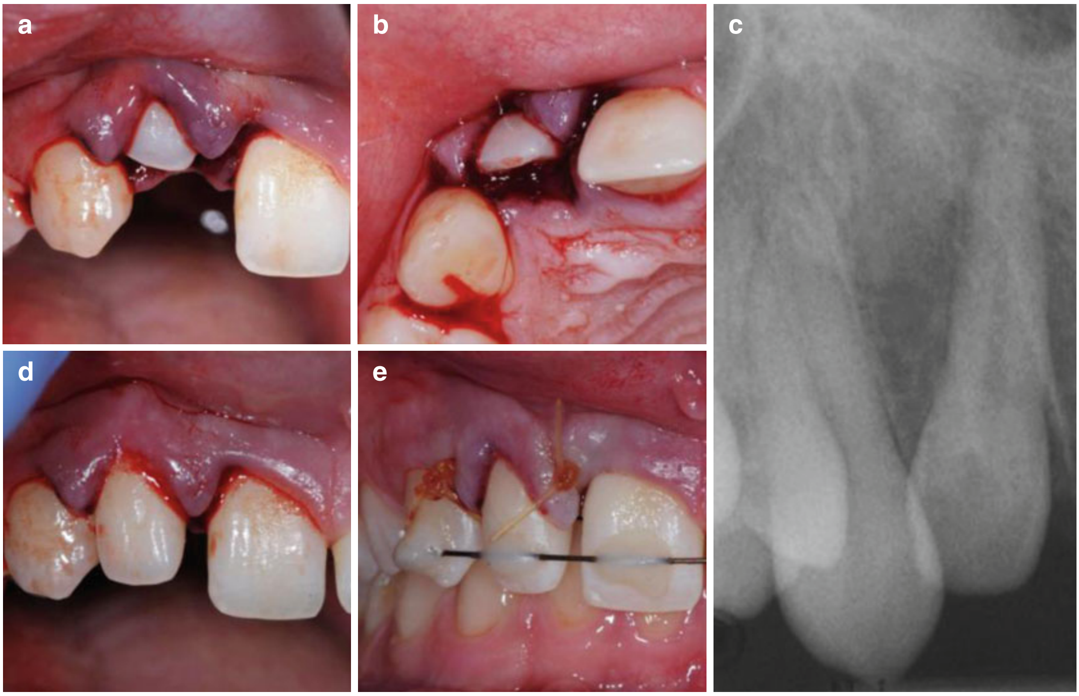

Fig. 15.16 Clinical photographs and radiograph demonstrating intrusive luxation injury affecting tooth 12. Note: (**a**, **b**) preoperative views demonstrating partial intrusion of tooth 12. (**c**) Periapical radiograph showing intruded lateral incisor tooth. (**d**) Repositioned tooth and (**e**) semirigid splint fixation used. The splint will be removed at 4–6 weeks, and provided there is no excessive mobility, the tooth will be monitored for signs of pulpal necrosis (Pictures courtesy of Drs K Dang and A Timmermann)

Recommended follow-up

Due to the high risks of pulp necrosis developing, close monitoring and follow-up are recommended. The patient should be reviewed at 4 weeks, 6–8 weeks, 6 months and 12 months thereafter following initial treatment.

15.7 Avulsion Injuries

Complete displacement of the tooth has occurred out of the socket. The periodontal ligament is severed and fracture of the alveolus may occur (Figs. 15.17, 15.18, and 15.19).

Immediate management at site of injury/telephone advice

An avulsed permanent tooth is one of the few real emergency situations in dentistry, and all dentists should have prior knowledge as to the management of such cases. Immediate management of an avulsed tooth includes the following points:

1. If a tooth is avulsed, check whether it is a permanent or primary tooth. Primary teeth should not be replanted due to risk of damaging the permanent successor.
2. Find the tooth and pick it up by the crown (the white part) and avoid touching any part of the root.
3. If the tooth is dirty, wash it briefly (maximum time 10 s) under cold running water prior to repositioning.
4. Try to encourage the patient/guardian to replant the tooth. Once the tooth is back in place, ask the patient to bite on a handkerchief to hold it in position.
5. If this is not possible, for example, in an unconscious patient, then place the tooth in a glass of milk or another suitable storage medium and bring it with the patient to the emergency clinic. The tooth can also be transported in the mouth, keeping it inside the lip or cheek if the patient is conscious. If the

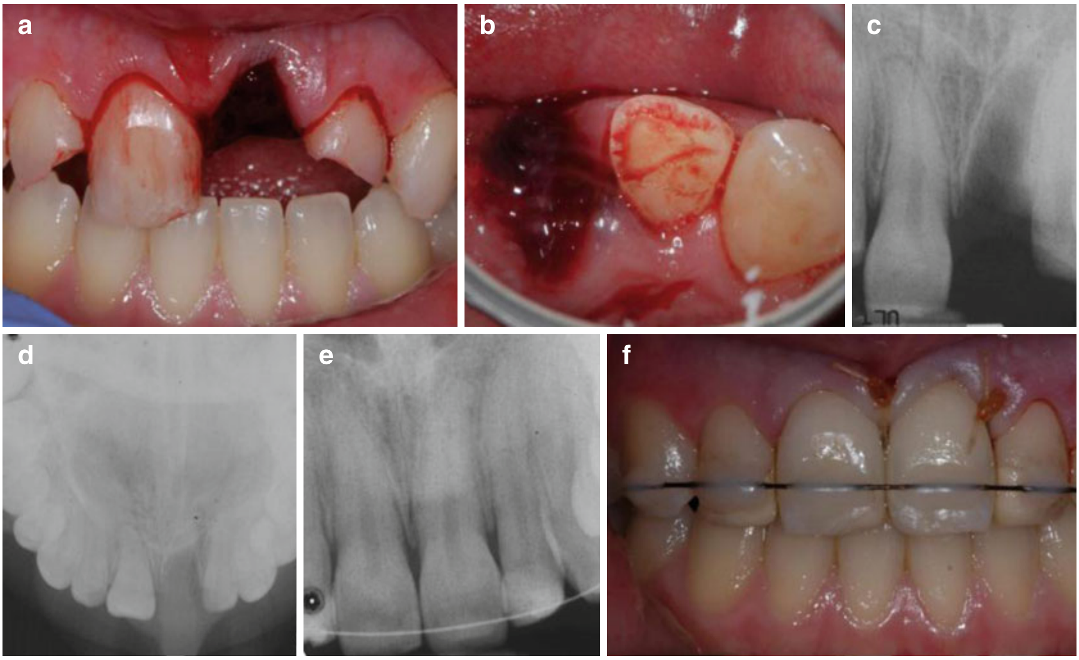

Fig. 15.17 Clinical photographs and radiographs demonstrating uncomplicated crown fractures associated with teeth 11, 12, and 22 and avulsion injury associated with tooth 21. Note: (**a**, **b**) uncomplicated crown fractures and avulsion injury to anterior maxillary dentition. (**c**, **d**) Preoperative parallel periapical and standard maxillary occlusal film to check for any undiagnosed root fractures. (**e**) Avulsed tooth replanted and (**f**) semirigid splint place. Root development is completed in this adult patient. The tooth will require endodontic therapy. Long-term sequelae include root resorption and ankylosis of the tooth (Pictures courtesy of Drs K Dang and A Timmermann)

patient is very young, it is advisable to get the patient to spit in a container and place the tooth in it due to the risk of ingestion or inhalation of the tooth. Avoid storage in water.

6. If there is access at the place of accident to special storage or transport media (e.g. tissue culture/transport medium, Hank's balanced salt solution (HBSS) storage medium or saline), such media can preferably be used.
7. Seek emergency dental treatment immediately.

Treatment guidelines for avulsed permanent teeth

The management of avulsion injuries is related to root maturation (open or closed apex) and whether the periodontal ligament (PDL) cells have survived. The condition and viability of the cells is dependent on the extra-oral time the tooth has remained out of the mouth (extra-oral dry time) and the storage medium used. After an extra-oral dry time of 60 min or more, all PDL cells can be considered non-viable. For this reason, it is very important to assess from the patient's history the extra-oral dry time and type of storage medium used.

Prior knowledge of the extra-oral dry time and storage medium used will aid the clinician in assessing the condition of the PDL cells, thereby classifying the avulsed tooth into *viable* (the tooth has been replanted immediately or after a very short time at the place of accident), *viable but compromised* (the tooth has been kept in a suitable storage medium (e.g. tissue culture, HBSS, saline, milk or saliva) and the total dry time has been less than 60 min) or *non-viable* (where the extra-oral dry time has been more than 60 min regardless if the tooth was stored in additional medium or not). The goal for replanting immature teeth (incomplete root development) in children is to allow for possible revascularisation of the pulp space.

Fig. 15.18 Clinical photograph showing multiple avulsed teeth in the upper anterior maxillary arch following a road traffic accident. Note: (**a**, **b**) extraoral views showing abrasions to mid-face. The patient had had a primary and secondary survey carried out revealing no underlying bony fractures. (**c**) Intraorally the patient had avulsed teeth 11, 12, and 21. (**d**) Avulsed teeth had been found at the scene of the accident and placed in milk. (**e, f**) Repositioned teeth with semirigid fixation. The teeth have a guarded long-term prognosis and will require endodontic intervention and long-term follow-up to ensure that no external replacement root resorption occurs (Pictures courtesy of Drs K Dang and A Timmermann)

The advantage of revascularisation in this situation lies in the possibility of continued root development and reinforcement of the dentinal walls by hard tissue deposition allowing further strengthening and reduced long-term propensity to root fracture. If that does not occur, root canal treatment may be recommended (see endodontic considerations). Replantation of adult mature teeth with closed apices has often been seen as a temporary measure with the risk of ultimately succumbing to root resorption. However there are many cases where teeth have survived, maintaining their integrity and function. It is therefore advisable that all teeth deemed viable should be replanted. Furthermore teeth that are deemed non-viable can be replanted with the knowledge that the risks of failure are greater (Figs. 15.17 and 15.18).

Treatment guidelines for avulsed permanent teeth with incomplete or complete root development and PDL cells are deemed viable.

If the tooth has already been replanted before the patient's arrival at the clinic, then leave the tooth in place. The site of injury is cleaned with water spray, saline or chlorhexidine. Gingival lacerations are sutured. The correct anatomical position of the replanted tooth is verified both clinically and radiographically prior to stabilisation with a flexible splint for up to 2 weeks. Systemic antibiotics may be administered. The patient's tetanus protection is checked and patient instructions are given including soft diet for up to 1 week. Root canal treatment may be initiated 7–10 days after replantation and prior to splint removal. Follow-up is always recommended.

Treatment guidelines for avulsed permanent teeth with incomplete or complete root development and PDL cells are deemed viable but compromised.

The root surface and apical foramen are cleaned with saline, and the tooth is soaked in saline, thereby removing contamination and dead cells from the root surface. Following local anaesthesia (see anaesthesia), the socket is irrigated with saline and examined for any alveolar socket fracture. If there is a fracture of the socket wall, reposition it prior to replanting the tooth. Replantation is carried out slowly with slight digital pressure without the use of any excessive force. Gingival lacerations are sutured, if present. The normal position of the replanted tooth is verified both clinically and radiographically prior to flexible splint application for up to 2 weeks. Administer systemic antibiotics and tetanus protection if required. The patient is given postoperative instructions (see Patient instructions). Root canal treatment is initiated 7–10 days after replantation and before splint removal (see Endodontic considerations). The tooth is followed up appropriately (see follow-up procedures).

Treatment guidelines for avulsed permanent teeth with incomplete or complete root development and PDL cells are deemed non-viable

Delayed replantation has a poor long-term prognosis. The periodontal ligament will be necrotic and is not expected to survive. The goals in delayed replantation are to restore aesthetics and function and to maintain alveolar bone contour. However, the expected outcome is ankylosis and resorption of the root resulting in eventual tooth loss. The technique for delayed replantation includes the removal of all attached non-viable soft tissue carefully using gauze. The procedure can be carried out mechanically with curettage or chemically using 17 % EDTA, citric acid or sodium hypochlorite solution. In an attempt to prevent or arrest osseous replacement of the tooth, treatment of the root surface with fluoride prior to replantation has been suggested (2 % sodium fluoride solution for 20 min). Emdogain consisting of hydrophobic enamel matrix proteins derived from porcine-developing embryonic enamel has also been used. It should be pointed out that the use of either treatment should not be seen as an absolute prerequisite in preventing/arresting osseous replacement. Root canal treatment to the tooth can be carried out prior to replantation or later (see endodontic considerations). Following administration of local anaesthesia (see anaesthesia), the socket is irrigated with saline and inspected for fracture of the socket wall (requiring repositioning if present). The tooth is replanted, and gingival lacerations are sutured, if present. Correct position of the replanted tooth is verified clinically and radiographically prior to stabilisation of the tooth with a flexible splint (for up to 4 weeks). Administration of systemic antibiotics (see antibiotics) and tetanus protection is advised (see Tetanus).

Careful follow-up is required, and good communication is necessary to ensure that both the patient and parent understand the likely outcome. Decoronation may be necessary later when more than 1 mm of infraposition is seen.

Anaesthesia

Patients and parents will often be advised to consider replanting the tooth at the place of accident without any local anaesthesia. When the patient is seen in the dental setting where anaesthesia is readily available, normal techniques should be considered. Traumatic

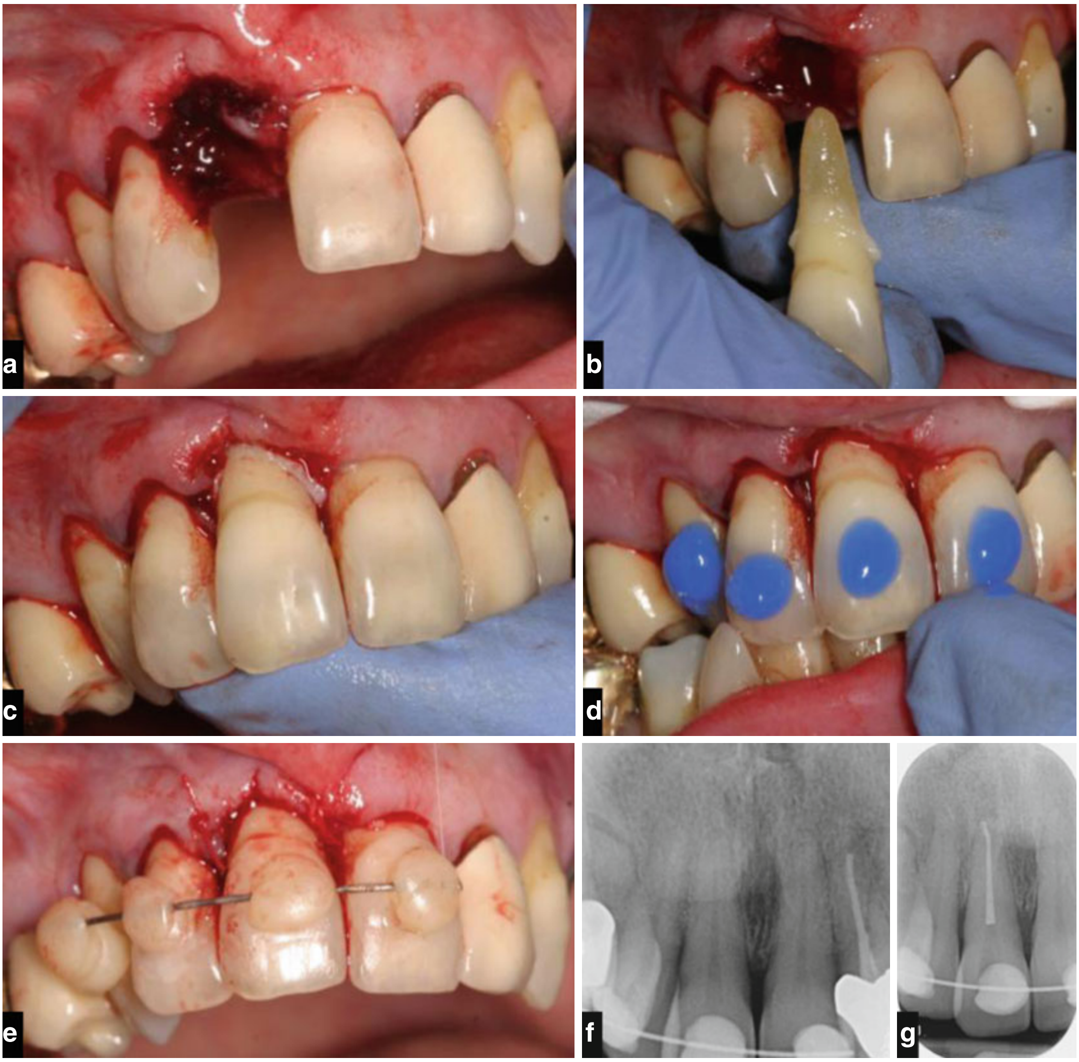

Fig. 15.19 Clinical photographs and radiograph showing management of avulsion injury in a fully developed permanent tooth 11 (extraoral dry period ideal). Note: (**a**) preoperative view showing avulsed tooth 11. (**b**) Tooth 11 is reimplanted with digital pressure. (**c**) Reimplanted 11. (**d**) Acid etch is applied to teeth prior to (**e**) flexible composite wire splint attachment. (**f**) Radiograph is taken to check position of replanted tooth 11. The patient is advised a soft diet, appropriate oral hygiene (chlorhexidine mouthwash), and oral antibiotics (100 mg doxycycline bd. 7 days provided not pregnant). (**g**) Root canal treatment is commenced 7–10 days later with an intracanal dressing of Ledermix and then calcium hydroxide (if resorption present) (Pictures courtesy of Ms Serpil Djemal)

dental injuries often present with concomitant injuries of the soft tissues including lacerations, which require suturing and therefore prior adequate anaesthesia. Concern is sometimes raised whether there are risks of compromising pulpal healing by using vasoconstrictor in the anaesthesia. No strong evidence is currently available for omitting vasoconstrictor.

Antibiotics

The use of systemic antibiotics as an adjunctive therapy in the management of avulsed permanent incisors (open or closed apices) has been recommended. The first choice is tetracycline (doxycycline twice daily for seven days). In many countries, systemic tetracycline use is not recommended for patients under 12 years of age due to the risk of discolouration in the developing permanent dentition. Penicillin (amoxicillin) can be given as an alternative to tetracycline (Fig. 15.19). Caution is also advised in pregnant patients and concomitant use of antibiotics and oral contraceptives.

Tetanus status

The patient should be advised to see their general medical practitioner for evaluation of need for a tetanus booster if the avulsed tooth has contacted soil or tetanus coverage is uncertain.

Splinting of replanted teeth

Splinting of luxated teeth is not only recommended to maintain the repositioned tooth in its correct anatomical position but also ensure that the patient is comfortable during the follow-up period as well as improve function. Current evidence supports short-term, flexible splints for stabilisation of replanted teeth. Studies have shown that for ideal periodontal and pulpal healing to occur the luxated tooth should not be completely rigid but allowed slight motion and the splinting time should not be overly extended. To date there is no specific type of splint related to healing outcomes. The splint should be placed on the buccal surfaces of the maxillary teeth and mandibular teeth to enable lingual access for endodontic procedures and to avoid occlusal interference. Various types of splints are available including resin, composite and wire, orthodontic brackets and titanium mesh. Acid-etch bonded composite splints using orthodontic wire have been widely used to stabilise teeth because fabrication in the dental setting is relatively straightforward. Furthermore, they allow good oral hygiene and are well tolerated by the patients (Fig. 15.19).

Patient instructions

To ensure satisfactory healing and the potential for optimal outcome, the patient must understand both aftercare instructions including home care advice and the need for follow-up evaluation. Patients/parents should be advised with regard to:

1. Avoiding participation in contact sports during the healing period; furthermore, a custom-made mouthguard would be advisable in the future.
2. Soft diet is recommended for up to 2 weeks to prevent further trauma to the dentition.
3. The patient is advised to brush teeth with a soft toothbrush after each meal.
4. The use of chlorhexidine (0.1 %) mouth rinse twice a day for 1 week is advisable. The patient should be warned of the possibility of staining of teeth.

Endodontic considerations

When root canal treatment is indicated, then the ideal time to begin treatment is 7–10 days post replantation. Calcium hydroxide is recommended as an intra-canal medication for up to 1 month followed by root canal filling with an acceptable material. Alternatively if an antibiotic-corticosteroid paste is chosen to be used as an anti-inflammatory, anticlastic intra-canal medicament, it may be placed immediately or shortly following replantation and left for at least 2 weeks. If the antibiotic in the paste is tetracycline, there is a risk of tooth discoloration.

If the tooth has been dry for more than 60 min before replantation, then the root canal treatment may be carried out extra-orally prior to replantation. The canal should be dressed with calcium hydroxide medicament to promote disinfection of the root canal and prevention of inflammatory root resorption. The dressing can be left in place for a longer follow-up period during which time the tooth can be assessed as to whether replacement root resorption has progressed.

In teeth with wide-open apices (immature incompletely developed roots), which have been replanted immediately or kept in appropriate storage media prior to replantation, pulp revascularisation may be possible. The risk of infection-related root resorption should be weighed up against the potential for pulp space revascularisation.

Follow-up procedures

Replanted teeth should be monitored both clinically and radiographically after 4 weeks, 3 months, 6 months, 1 year and yearly thereafter. Percussion tenderness, palpation tenderness, colour, mobility, periodontal probing profile and sensibility test testing (electric pulp testing and thermal stimulus) and appropriate parallel periapical radiographs should be recorded at review appointments.

Loss of tooth

Dental traumatic injuries including avulsion injuries often affect maxillary central incisors and often occur before the age of 18 years. Replantation of avulsed teeth gives rise to complications including replacement root resorption (ankylosis) and external inflammatory resorption. Whilst appropriate endodontic therapy is effective in the treatment of external inflammatory resorption, replacement resorption cannot be arrested or repaired. Replacement resorption occurs due to the absence of vital periodontal ligament resulting in normal osteoclastic activity causing bone remodelling and tooth resorption. Under normal bone remodelling, the root is continuously resorbed and replaced with the bone. In an adult mature tooth, no clinical signs and symptoms exist other than a metallic sound in response to percussion testing. In immature teeth as growth continues, the ankylosed tooth will result in infraocclusion. Treatment options include either decoronation aimed at preserving the tooth in situ where continued alveolar growth is expected (immature teeth) or extraction and prosthodontic replacement (mature teeth). Restoring teeth in growing patients poses a unique set of problems associated with aesthetic and function. One must bear in mind that the ideal replacement of a missing tooth with a solitary implant by virtue of osseointegration will result in ankylosis and infraocclusion in the growing patient. Often an interdisciplinary approach is recommended depending on the treatment plan proposed. Options for replacement of an unsuccessful avulsed tooth lost prematurely include replacement with autotransplantation, use of a single-tooth implant prosthesis, orthodontic closure of the space or space maintenance using a removable denture, resin-bonded bridge or fixed bridgework. Crown and bridgework should be avoided in the growing patient where similar to alveolar growth the gingival margin continues to mature to the cement-enamel junction resulting in exposed roots and unsightly aesthetics at the gingival margin if early treatment is provided before gingival maturation has occurred (age 18+).

Treatment Summary for an Avulsion Injury

Clinical and Radiographic Findings

- Clinical and radiographic findings reveal either the tooth is not in the socket or the tooth has already been replanted.
- Radiographic evidence will confirm the tooth is not intruded when the tooth has not been found.

Treatment Objectives

- To replant the tooth into its anatomically correct position as soon as possible to optimise healing of the periodontal ligament and neurovascular supply whilst maintaining aesthetics and function.
- Stabilisation using a flexible splint for 2 weeks.
- Tetanus prophylaxis and antibiotic coverage should be considered.
- Treatment strategies are aimed at avoiding inflammation that may occur as a result of the tooth's attachment damage and/or pulpal inflammation.
- Choice of treatment is related to the *maturity of the root* (open or closed apex) and *the condition of the PDL cells* (viable or non viable). The condition of the cells is dependent on the storage medium and the time out of the mouth. Note the extra-alveolar dry time is critical for survival of the cells. After a dry time of 60 minutes or more all PDL cells are non-viable. For this reason, the dry time of the tooth, before it was replanted or placed in a storage medium, is very important to assess from the patient's history.
- *The PDL cells are most likely viable*. The tooth has been replanted immediately or after a very short time at the place of accident. Initiate root canal treatment in mature teeth 7–10 days after replantation and before splint removal. In immature teeth (not fully developed) it may be worthwhile waiting for possible revascularization of the pulp space. If this does not occur then root canal treatment will be necessary.
- *The PDL cells may be viable but compromised*. The tooth has been kept in storage medium

(e.g. tissue culture medium, HBSS, saline, milk or saliva and the total dry time has been less than 60 min). In mature teeth initiate root canal treatment 7–10 days after replantation and before splint removal. In immature teeth you must weigh up the potential of possible revascularization against the risk of infection related root resorption. Such resorption can be very rapid in children and so careful follow up will be required with the possibility of endodontic intervention where necessary.

- *The PDL cells are non-viable*. The total extra-oral dry time has been more than 60 min. The PDL will be necrotic and not expected to heal. Non-viable soft tissue is carefully removed. In both mature and immature teeth root canal treatment can be done either on the tooth prior to replantation or 7-10 days after replantation and splint removal. In order to slow down osseous replacement of the tooth, treatment of the root surface with fluoride prior to replantation has been suggested (2% sodium fluoride solution for 20 min) but it should not be seen as an absolute recommendation.
- Consider decoronation procedures when clinical infraposition of the tooth appear and/or clinical and radiographic findings of anyklosis are present.

General Prognosis

- Pulp necrosis, external inflammatory root resorption, ankylosis and replacement resorption are common healing complications.

Recommended Follow-Up

- Splinting 2–4 weeks depending on extra-oral dry time period
- General follow up should be at 4 weeks, 6–8 weeks, 6 months, 1 year and yearly up to 5 years.
- In immature teeth where revascularization is being monitored teeth should be reviewed every 4weeks with appropriate pulp testing and radiographs.

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