Article history:
Received: 15 February 2025
Accepted: 20 March 2025
Available online: 25 March 2025
UDC: 616.314-001.5-08
DOI: 10.70113/1815-9443.2025.16.90.006

CURRENT RECOMMENDATIONS FOR THE MANAGEMENT OF TRAUMATIC DENTAL INJURIES

Dide Tekinarslan, Kürşat Er
Department of Endodontics, Faculty of Dentistry, Akdeniz University, Antalya, Türkiye

Introduction:
Traumatic dental injuries (TDIs) are a significant concern, especially in children and adolescents, as they often result in complex injuries to the teeth, supporting bone, and surrounding soft tissues. The increasing prevalence of such trauma in younger populations makes it a crucial subject in contemporary dental practice. These injuries can range from mild enamel fractures to serious luxations and avulsions, with long-term implications for oral health, function, and aesthetics.
Methods:
This narrative review analyzes current evidence and clinical recommendations for the management of TDIs, focusing on the latest updates from the International Association of Dental Traumatology (IADT). The study involved an in-depth review of the types of dental injuries, clinical and radiographic examination protocols, pulp vitality assessment tools, and intervention strategies such as splinting, replantation, and antibiotic administration.
Results:
Proper diagnosis and timely management are crucial for preserving dental structures and preventing long-term complications, particularly in young patients with developing dentition and immature root structures. The management approach depends on the type and severity of the injury, with a special focus on pulp vitality preservation and the appropriate use of splints and antibiotics. Clinical techniques, such as sensibility and vitality tests, assist in monitoring pulp status, while interventions like partial and full pulpotomy are increasingly used to maintain pulp health. Additionally, adherence to IADT guidelines ensures standardized care across various types of injuries, including fractures, luxations, and avulsions. These guidelines emphasize not only initial management but also the necessity of long-term follow-up and patient compliance.
Conclusion:
Through proper adherence to these guidelines, dental professionals can mitigate complications like pulp necrosis, root resorption, and tooth loss, ultimately improving long-term outcomes for patients. The integration of evidence-based protocols into clinical practice supports optimal healing and reduces the burden of trauma-related sequelae in both pediatric and adult populations.
Keywords: Trauma, guideline, fracture, splint, treatment, pulp vitality, IADT.

ТІС-ЖАҚ ЖАРАҚАТТАРЫН ЕМДЕУ БОЙЫНША ҚАЗІРГІ ҰСЫНЫСТАР

Диде Текінарслан, Күршат Ер
Эндодонтия кафедрасы, Стоматология факультеті,
Акдениз университеті, Анталья, Түркия

Кіріспе:
Тіс-жақ жарақаттары (ТЖЖ), әсіресе балалар мен жасөспірімдер арасында, жиі кездесетін және күрделі жағдайларды тудыратын маңызды мәселе болып табылады. Бұл жарақаттар тістерге, тірек сүйектерге және жұмсақ тіндерге әсер етеді және жеңіл эмаль сынуынан бастап ауыр шығулар мен толық авульсияларға дейін өзгеруі мүмкін. Жас науқастарда, әсіресе жетілмеген

түбірі бар тістерде, мұндай жарақаттардың салдарын азайту үшін дұрыс диагностика мен уақтылы емдеу өте маңызды.

Әдістер:

Бұл шолу қазіргі ғылыми әдебиеттерді және Тіс жарақаттары жөніндегі халықаралық қауымдастық (IADT) ұсынған соңғы хаттамаларды талдау арқылы жүргізілді. Зерттеу барысында клиникалық және рентгенологиялық тексерулер, пульпа виталдылығын бағалау, шинирлеу әдістері, реплантация және антибиотиктерді қолдану бойынша заманауи ұсыныстар қарастырылды.

Нәтижелер:

Тиімді емдеу науқастың жасына, жарақаттың түрі мен ауырлығына байланысты белгіленеді. Пульпа виталдылығын сақтау, шинирлеудің дұрыс түрін таңдау және антибиотиктерді дәлелді қолдану – негізгі факторлар. Пульпаны сақтау мақсатында жартылай немесе толық пульпотомия сияқты эндодонтиялық араласулар жиі қолданылады. IADT хаттамалары жарақаттың түріне қарай жедел және ұзақ мерзімді күтімге нақты нұсқаулар береді, сондай-ақ науқастың бақылау қабылдауларына қатысуын ерекше атап көрсетеді.

Қорытынды:

Халықаралық ұсыныстарды дұрыс қолдану арқылы стоматологтар пульпа некрозы, түбірдің резорбциясы және тісті жоғалту сияқты асқынулардың алдын алып, науқастар үшін ұзақ мерзімді оң нәтижелерге қол жеткізе алады.

Түйінді сөздер: Жарақат, нұсқаулық, сыну, шина, емдеу, пульпа виталдылығы, IADT.

ТЕКУЩИЕ РЕКОМЕНДАЦИИ ПО ЛЕЧЕНИЮ ТРАВМАТИЧЕСКИХ ПОВРЕЖДЕНИЙ ЗУБОВ

Диде Текінарслан, Кюршат Эр
Кафедра эндодонтии, Стоматологический факультет,
Университет Акдениз, Анталья, Турция

Введение:

Травматические повреждения зубов (ТПЗ) представляют собой серьёзную проблему, особенно среди детей и подростков, поскольку часто сопровождаются комплексными поражениями зубов, альвеолярной кости и окружающих мягких тканей. Эти повреждения варьируются от незначительных сколов эмали до тяжёлых вывихов и авульсий. С учётом высокой распространённости ТПЗ среди молодого населения вопрос своевременной диагностики и лечения становится особо актуальным.

Методы:

В данной обзорной работе проанализированы современные рекомендации по лечению ТПЗ с акцентом на обновлённые руководства Международной ассоциации по стоматологической травматологии (IADT). Особое внимание уделено клиническим и рентгенологическим методам обследования, оценке витальности пульпы, а также протоколам лечения, включая шинирование, реплантацию и использование антибиотиков.

Результаты:

Правильная диагностика и своевременное вмешательство играют ключевую роль в сохранении анатомических структур зуба и профилактике отдалённых осложнений, особенно у пациентов с несформированными корнями. Подход к лечению зависит от типа и степени повреждения, при этом особый акцент делается на сохранение витальности пульпы и обоснованное применение шин и медикаментозной терапии. Также рассматриваются такие методы, как частичная и полная пульпотомия, показавшие высокую эффективность. Руководства IADT содержат чёткие рекомендации по неотложной и долгосрочной помощи, подчёркивая важность регулярных осмотров и соблюдения пациентом рекомендаций.

Заключение:

Соблюдение современных клинических протоколов позволяет минимизировать риск осложнений, таких как некроз пульпы, резорбция корня и потеря зуба, а также способствует улучшению долгосрочного прогноза для пациентов с травмами зубов.

Ключевые слова: травма, протокол, перелом, шинирование, лечение, витальность пульпы, IADT.

Introduction

Traumatic dental injuries (TDIs) are frequently accompanied with complicated injuries such as fracture and displacement of teeth and bone, as well as soft tissue injuries such as laceration, abrasion, and contusion, all of which require accurate diagnosis and treatment [1]. The majority of TDIs occur between the ages of 8 and 12, during orofacial growth and permanent teeth, and account for 5% of all injuries [1]. Mostly maxillary incisors are affected by trauma [2]. Luxation injuries are the most common TDIs among primary dentition and crown fractures are commonly seen in permanent dentition [3].

Proper diagnosis and treatment are critical in early permanent dentition, as the teeth have thin dentinal walls and open apices. It is important to know the type and extension of trauma, correct treatment, and assess the stage of root development. For this purpose, the International Association of Dental Trauma (IADT) Guidelines provide information about the immediate care of TDIs. These guidelines recommend for the diagnosis and treatment of TDIs. The dental trauma guidelines can be found at http://www.dentaltraumaguide.org. It can also be considered in the Krastl et al. [4] article.

1. Examination

1.1. Clinical Examination

Percussion, palpation, pulp testing, mobility assessment, and radiographic analysis are all part of the clinical diagnosis process (Fig. 1). Particularly after luxation injuries, temporary loss of sensitivity is frequently experienced during post-traumatic pulp healing [5]. Consequently, pulp necrosis should not be confused with pulp sensibility loss. However, it is a necessary process for every follow-up because it can affect the treatment process. The patient's tetanus vaccination status should also be evaluated. Follow-ups are essential after TDIs. Pulp necrosis and infection, pulp space obliteration, and different forms of root resorption are the main post-traumatic consequences. A better prognosis is a result of early identification and treatment of these issues.



Figure 1 - Clinical examination; *(a)* percussion, *(b)* mobility examination, *(c)* pulp testing, *(d)* palpation.

1.2. Radiographic Examination

Radiographic examination plays a crucial role in assessing TDIs. It helps in evaluating the extent of injury to teeth, surrounding tissues, and the jaw. During this period, the use of film holders is recommended to

facilitate the standardization of radiographs [1]. Periapical, bitewing and panoramic X-rays are helpful in detecting fractures. Cone beam computer tomography (CBCT) imaging should be considered if it's available [6]. It provides a three-dimensional view of the teeth, jaws, and facial structures. It is especially useful in cases of complex trauma, such as fractures or avulsed teeth, where treatment planning calls for specific information.

To assess the immediate damage, a series of radiographs should be taken as soon as possible after the injury. Depending on the trauma, follow-up radiographs may be necessary to monitor healing and detect any delayed complications, such as resorption or pulp alterations.

1.3. Photographic Documentation

Photographic documentation of dental trauma cases plays a critical role in both the clinical and legal aspects of dental care. Accurate and comprehensive images are useful for diagnosis, treatment planning, and follow-up. They also help in assessing the severity of the injury and can serve as an important tool for tracking progress over time. For example, Figure 2 shows photographic records from the clinical treatment processes of an extrusion trauma case.



Figure 2 - Clinical photographs of extrusion of left maxillary central incisor and it's follow-up.

1.4. Pulp Status Evaluation

1.4.1. Sensibility Test

"Sensibility testing" which includes thermal (especially cold) and electric pulp tests, is employed to evaluate the state of the pulp. This testing evaluates neural activity rather than vascular supply. Thermal tests trigger the hydrodynamic movement of fluid within dentinal tubules, which excites the A-delta nerve fibers, whereas electric pulp tests result in the direct stimulation of the A-delta fibers [7]. After trauma, neural regeneration occurs at a slower rate than vascular regeneration and may even fail to reappear, which contradicts the nature of sensibility testing [8]. Therefore, this testing may be unreliable due to the temporary absence of neural response or the undifferentiated state of nerve fibers in young teeth [9]. Temporary loss of sensibility is commonly observed during post-traumatic pulp healing, particularly following luxation injuries [5]. Consequently, the absence of a response to pulp sensibility testing does not definitively indicate pulp necrosis in traumatized teeth.

1.4.2. Vitality Test

Vitality tests (e.g. laser Doppler flowmetry, pulse oximetry) assess the blood supply of the pulp. These approaches, which measure actual blood flow rather than neural reaction, have proved reliability as a non-invasive and precise method for validating the presence of a blood supply (vitality) in the pulp [9,10].

Pulse oximetry (PO) is a method of monitoring oxygen saturation in the blood and the patient's pulse rate. The concepts of PO are based on a modification of Beer's law and haemoglobin absorption characteristics in the red and infrared spectrum. Its probe comprises of a photodetector and 2 light-emitting diodes (LED). One LED transmits red light (640 nm) to the vascular tissue, while the other transmits infrared light (960 nm). Oxygenated and deoxygenated haemoglobin absorb varying amounts of red and infrared light. The pulsating change in blood volume causes periodic changes in the amount of red and infrared light absorbed by the vascular tissue before reaching the photodetector, and PO uses this information to calculate the pulse rate and oxygen saturation [11]. Another technique used for the pulp vitality measurement is laser Doppler flowmeter (LDF). It assesses dynamic changes in blood flow using noninvasive measurement techniques that detect blood cell movement in a small volume of tissue. The flow in individual microvessels, the number of vessels with active flow, and the vessel diameter

cannot be analyzed, but total flow can be monitored throughout the tissue. In the orofacial region, the perfusion of gingiva, bone, and masticatory muscles and the pulpal blood flow have been explored. Answers to several concerns, such as estimating pulpal vitality, monitoring tooth vitality after trauma, reactions to local and systemic pharmacological agents, pulpal response to electrical and thermal stimulation, and orthodontic and orthognathic operations, have been sought. However, there are several factors that affect LDF measurements. For example, the patient's sitting position in the unit, whether they exerted effort before the measurement, the position of the probe on the tooth surface, and misleading data obtained from surrounding tissues in measurements made without isolators like rubber dams [12-15]. Therefore, measurements taken without paying attention to these confounding factors in LDF measurements may yield incorrect results.

1.4.3. Splinting

Splinting in dental trauma is a procedure for stabilizing dislocated teeth caused by an injury. It is intended to provide support that permits sufficient healing, frequently by holding the damaged tooth in place for a while to prevent additional harm and promote healing of the supporting tissues.

Short-term, passive, and flexible splints are lately favorable for the splinting of luxated, avulsed, and root-fractured teeth. In cases involving alveolar bone fractures, tooth splinting may be utilized for immobilizing bone segments. The duration (usually for 1-4 weeks) of splinting will vary depending on the type of injury, tooth mobility, and healing progress. In some cases, they may need to be adjusted or changed.

Follow-up visits are necessary to monitor healing and detect issues such as root resorption or infection. Patients should avoid applying excessive force to splinted teeth and it may be advised to eat soft foods.

1.5. Antibiotics

Antibiotics are occasionally used in the treatment of dental trauma, particularly when there is an open wound, severe soft tissue injury, or infection risk. Generally, they might not be required if the injury is mild, not causing any serious soft tissue damage, and there is no chance of infection. But, antibiotic treatment may be required in the presence of wounds that cannot be easily cleaned or are located in areas with poor blood flow, making healing problematic, in people with weakened immune systems, and in cases of severe trauma. Therefore, antibiotic administration remains at the discretion of the clinician.

1.6. Patient Instruction

Patient compliance with follow-ups and home care significantly enhances healing following a TDI. It's imperative to educate on caring for the injured tooth or teeth and surrounding tissues to promote optimal healing, emphasizing meticulous oral hygiene practices, and recommending rinsing with an antibacterial agent like chlorhexidine (CHX).

1.7. Follow-up

Follow-ups are essential after TDIs to ensuring the damage is correctly addressed and avoiding long-term consequences. Each visit should involve questioning the patient about any signs or symptoms, along with comprehensive clinical and radiographic examinations, including pulp sensibility testing. The primary post-traumatic complications include pulp necrosis and infection, pulp space obliteration, various types of root resorption, as well as breakdown of marginal gingiva and bone. Early detection and management of these complications significantly improve prognosis.

2. Types of Dental Traumas

2.1. Crown Fractures (CFs)

An incomplete fracture or crack of enamel without loss of tooth structure is often referred to as an enamel infraction. Fractures involving only the enamel and dentin without pulp exposure are termed uncomplicated CFs. If the pulp is involved in this fracture, it is called complicated CF [16].

2.1.1. Enamel Infraction

An enamel infraction is a minor type of TDI that involves a crack or fracture in the tooth's enamel, which is the hard outer layer of the tooth. It's typically a small, shallow crack that doesn't affect the underlying dentin or pulp. Enamel infractions rarely cause discomfort, and many individuals may not detect them. On a tooth that is affected by enamel infraction, there is no sensitivity for percussion or palpation, there is normal mobility and usually positive pulp sensitivity (Figure 3). In cases of severe infractions, it is advisable to consider etching and sealing with bonding resin to prevent discoloration and bacterial contamination of the infractions. Otherwise, no treatment may be necessary. No follow-up is necessary.



Figure 3 - Enamel infraction of maxillary right canine tooth.

2.1.2. Uncomplicated CF

If a tooth is affected by an uncomplicated CF, there is a loss of enamel, usually positive pulp sensitivity and normal mobility (Figure 4). If the tooth fragment is accessible, it can be reattached to the tooth. Alternatively, based on the severity and location of the fracture, the tooth edges can be refined, or a composite resin restoration may be applied. Clinical and radiological follow-up is necessary after 6-8-week, 1-year.



Figure 4 – Uncomplicated crown fracture of maxillary right central incisor

2.1.3. Complicated CF

In complicated CFs, there are enamel and dentin fractures with pulp exposure (Fig. 5). There is normal mobility, no sensitivity for percussion and palpation, exposed pulp is sensitive to stimuli (cold, heat, sweets, etc.). If the fragment is missing, and there are soft tissue injuries, it is recommended to take radiographs of the lip and/or cheek to search for tooth fragments and/or foreign debris. In patients with immature roots and open apices, preserving the pulp is crucial. Partial pulpotomy or pulp capping is recommended to promote further root development. In teeth with large pulp exposures, cervical pulpotomy can be applied. If a post is necessary for crown retention in a mature tooth with complete root formation, root canal treatment (RCT) is the preferred option. If the tooth fragment is available, it can be bonded back onto the tooth after rehydration, and the exposed pulp is treated. In the absence of

an intact crown fragment for bonding, cover the exposed dentin with glass ionomer or use a bonding agent and composite resin. Some of the cases, clinicians may also use surgical or orthodontic extrusion treatment options. Clinical and radiologic follow-up is necessary after 6-8-week, 3-month, 6-month and 1-year [1-5].



Figure 5 - Complicated crown fracture of maxillary left central incisor

2.2. Crown-Root Fractures

2.2.1. Uncomplicated Crown-Root Fracture

A fracture that involves enamel, dentin and cementum without pulp tissue is referred to as uncomplicated crown-root fracture. The fracture line usually extends below gingival margin in this kind of fracture. Pulpal sensitivity test is usually positive and there is a tenderness to percussion. Broken fragments are usually present and mobile. The extent of the fracture should be evaluated. If the broken fragments are missing, soft tissues should be checked to eliminate fragment embedding. For soft tissue control, at least 2 radiographs with different angles should be obtained: 1 parallel periapical, and 1with different vertical or horizontal angulation. Until a final treatment plan is decided, the broken fragment should splint to adjacent or non-loose teeth for stabilization [1-3]. If the pulp is not exposed, mobile fragments should be extracted, and restoration should be considered. Future treatment options depend on the patient's age and cooperation. Apical part can be extruded by orthodontic or surgical extrusion, and then restoration can be finished. If the tooth becomes necrotic RCT and then restoration should be considered. The treatment should follow 1-week, 6-8-week, 3-month, 6-month, 1-year and then yearly for 5-year [1-5,16].

2.2.2. Complicated Crown Root Fracture

This fracture contains enamel, dentin, pulp, and cementum (Fig. 6). All the clinical and radiographic examinations are the same with uncomplicated crown root fracture, but treatment options can differ due to it containing pulp tissue. Again, the broken fragment should splint for stabilization. If the traumatized tooth is immature with incomplete root formation; preserving the pulp vitality is crucial. For this purpose, partial pulpotomy is recommended. If the tooth is mature with complete root formation; removal of the pulp tissue is recommended. The follow-up procedures are the same with uncomplicated crown-root fractures.



Figure 6 - Complicated crown root fracture of maxillary right central incisor

2.3. Root Fracture

These fractures contain cementum, dentin and pulp. The fracture can be horizontal, oblique or a combination of both. The coronal segment may be mobile or displaced. Bleeding from gingival sulcus can be seen. Tooth is tender to percussion and there may be negative pulpal sensitivity due to neural damage. Radiographs with different angulations should be captured due to fracture levels may differ (Figure 7).

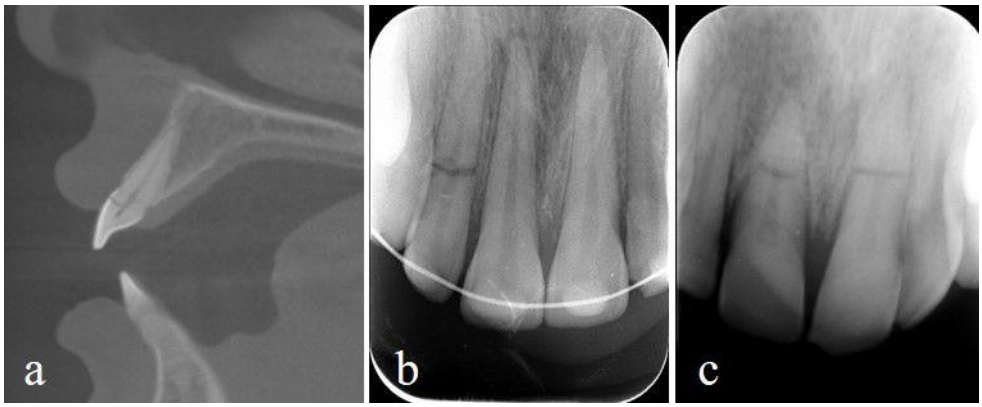


Figure 7 - Root fracture at *(a)* cervical, *(b)* middle, and *(c)* apical site of the tooth

If the coronal fragment is displaced, the fragment should be repositioned immediately. Reposition should be checked with radiography. To stabilize the mobile coronal segment flexible, non-rigid splint is recommended for 4-week. Emergency RCT shouldn't be initialized at first visit due to the cervical fracture healing. It is advised that the pulp status and healing of root fractures should be monitored for a year. Usually, the coronal segment is affected by the pulpal necrosis. Thus, only the coronal segment requires RCT. In oblique root fracture, it is challenging to obtain correct working length. If the fracture is above the crestal bone and the cervical fragment is mobile, the cervical fragment can be extracted and then RCT and restoration with fiber post should be applied. After 4-week splint should remove and follow-ups should be after 6-8-week, 3-month, 6-month, 1-year, then yearly up to 5-year [1-5,16].

2.4. Alveolar Bone Fracture

This injury comprises a fracture of the alveolar bone, which may spread to adjacent bone fractures. Segmental mobility and the presence of more than one tooth are common. Due to displacement and mobility, occlusal changes can be seen as well. Radiographs with 2 different angulation and occlusal radiographs are advised. CBCT images can determine the extent of the fracture. Replacement of the displaced segment is required. Stabilization with a non-rigid, flexible splint for 4-week is recommended. If there is any gingival laceration, they should suture. At emergency care immediate RCT is contraindicated. Pulp vitality should be obtained at every visit and treatment should be applied if

necessary. At 4-week splint should be removed and clinical, radiographic evaluation is necessary after 6-8-week, 3-month, 6-month, 1-year, then yearly up to 5-year [1-3].

2.5. Luxation Injuries

2.5.1. Concussion

It is a supporting tissue injury that makes the tooth significantly sensitive to percussion without causing abnormal loosening or displacement. There will be no radiographic abnormalities. In this kind of trauma, no treatment is necessary, just monitoring pulp vitality is recommended. Soft dietary can be recommended to the patient. Follow-ups are necessary at 4-week and 1-year.

2.5.2. Subluxation

An injury to the supporting structures of the tooth characterized by abnormal loosening but without displacement of the tooth is often referred to as subluxation. The tooth is tender to percussion due to its mobility. Bleeding from gingival sulcus may be seen. The vitality of pulp can be negative due to trauma. Radiographic images are normal. Normally in these injuries, there is no treatment needed. A passive and non-rigid splint is recommended for 2-week. Soft dietary is mandatory. Pulp vitality should be monitored. After 2-week splint should be removed and follow-ups should be after 12-week, 6-month and 1-year [1-5].

2.5.3. Extrusive Luxation

The term extrusion luxation is commonly used to describe the displacement of the tooth out of its socket in an incisal/axial direction. The tooth is mobile and seems elongated incisally from its socket (Fig. 8). Pulp sensitivity tests are usually negative. Radiographically periodontal ligament space widened apically and laterally.



Figure 8 - Extrusive luxation of left maxillary central incisor

Reposition the tooth by gently guiding it back into the tooth socket under local anesthesia. Stabilize the tooth for 2-week using a passive and non-rigid splint. In cases of breakdown or fracture of the marginal bone, extend splinting for an additional 4-week. Regularly control the pulp sensitivity. If the pulp becomes necrotic an RCT that is suitable to root development is advised. Clinical and radiological follow-ups should start, and splint should be removed after 2-week, then continue at 4-week, 8-week, 12-week, 6-month, 1-year, then yearly up to 5-year [1-3].

2.5.4. Lateral Luxation

The displacement of the tooth in any lateral direction, typically associated with a fracture or compression of the alveolar socket wall or facial cortical bone, is often termed lateral luxation (Fig. 9). The tooth is usually displaced to palatal or labial direction and usually immobile because it is locked at the fractured bone segment. Ankylotic (metallic) sound can be heard when percussion is performed.

Pulp vitality is likely to be negative. In radiographs with horizontal angulation, it can be seen that the widening of periodontal ligament space.

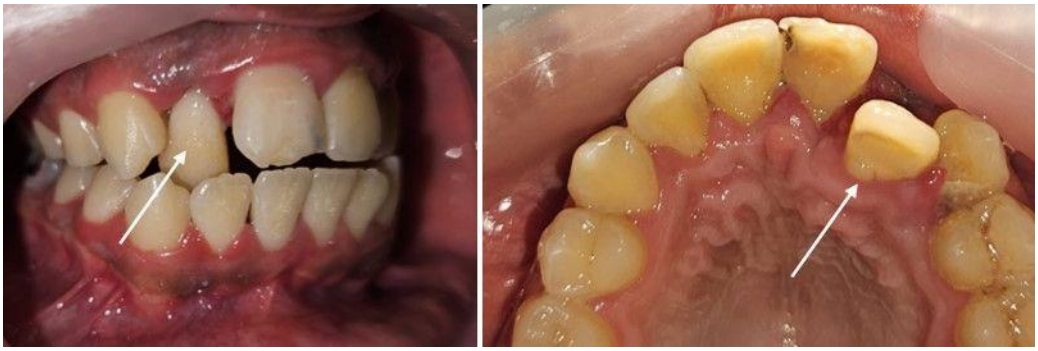


Figure 9 - Lateral luxation of right maxillary right lateral incisor.

Repositioning the tooth digitally involves carefully disengaging it from its locked position and gently guiding it back to its original location under local anesthesia. First, palpate the gingiva to locate the tooth's apex. Employ one finger to apply gentle downward pressure over the apical end. Simultaneously, use another finger or thumb to delicately guide the tooth back into its socket. To ensure stability use a passive and non-rigid splint for 4-week. In cases of fracture of the marginal bone or alveolar socket wall, consider additional splinting. At follow-ups, pulp vitality should be checked. After 2-week, endodontic reevaluation should be done. For teeth with immature root formation, revascularization may be happening. But if there is a sign of pulp necrosis RCT is indicated. In teeth with mature root formation, the pulp will probably be necrotic and RCT should be applied with CH intracanal medication due to inflammation. Clinical and radiological follow-ups should start after 2-week and after 4-week splint should be removed, then continue at 8-week, 12-week, 6-month, 1-year, then yearly up to 5-year [1-5,16].

2.5.5. Intrusive Luxation

Displacement of the tooth in an apical direction into the alveolar bone is commonly referred to as intrusive luxation. The tooth is displaced into the alveolar bone and percussion sounds ankylotic (metallic). Pulp sensitivity tests are usually negative. In radiographic assessment, periodontal ligament space is not visible and cementoenamel junction is located more apically than adjacent teeth.

For immature teeth, re-eruption (spontaneous eruption) may happen, irrespective of the degree of intrusion. If re-eruption doesn't occur within 4-week, initiate orthodontic repositioning and regularly assess pulp sensitivity. In teeth with immature root formation, spontaneous revascularization may occur. However, if there is pulp necrosis or external resorption immediately start RCT.

For mature teeth, if the tooth is intruded less than 3 mm follow for re-eruption without intervention. However, if there is no sign of re-eruption within 8-week, surgical repositioning can be performed and should be splinted with passive and non-rigid splint for 4-week. Also, before the development of ankylosis, orthodontically eruption can be considered. If the tooth is intruded between 3-7 mm, preferably surgical or orthodontic extrusion may be considered. Surgical repositioning is recommended if the intrusion is beyond 7 mm. In teeth with mature root formation, after intrusion traumas pulp become almost always necrotic and RCT must be initiated at 2th week, for intra-canal medicament CH can be used. The purpose of medicaments is to prevent external resorption. Clinical and radiological follow-ups should start after 2-week and after 4-week splint should be removed, then continue at 8-week, 12-week, 6-month, 1-year, then yearly up to 5-year [1,3].

2.5.6. Avulsion

Avulsion is one of the most serious injuries and tooth survival depends on the treatment time and protocols (Fig. 10). In permanent dentition, avulsion injury takes 0.5-16% of all injuries [16]. In most cases, replantation is the treatment but can depend on various conditions like periodontal health, patient cooperation, and systematic disease. A recent study showed that replantation of the avulsed tooth with IADT guidelines has a better prognosis than previous treatments [17].

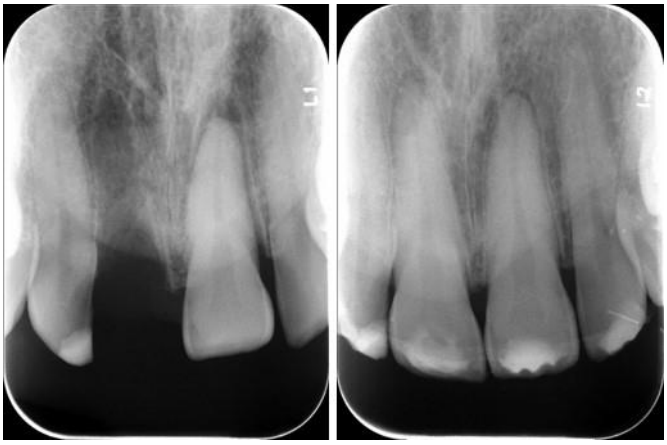


Figure 10 - Avulsion of right maxillary central incisor

The treatment choice depends on root formation (open, closed) and periodontal ligament status (extraoral time) of the avulsed tooth [17]. Avulsed teeth should keep in wet conditions like; milk, saline, patient's saliva. If the extraoral time expands more than 30 min the chance of pulp vitality significantly decreases [19].

2.5.6.1. Treatments for Permanent Teeth with Closed Apex

2.5.6.1.1. The Tooth Has Been Replanted at the Site of Injury

Clean the traumatized area with water, saline or CHX. Check the accuracy of replanted tooth clinically and radiographically. If it is accurate leave it, if it isn't making corrections by applying slight pressure. If the tooth needs position correction, do it within 48 h. While correction if anesthesia is required, use local anesthesia without a vasoconstrictor. The tooth should be stabilized with a passive, non-rigid splint for 2-week. Alternatively, nylon fishing lines can be used, due to their flexibility. If there is an alveolar bone fracture present, a more rigid splint for 4-week is recommended. RCT should initiate within 2-week after replantation. Tetanus vaccination status should be checked. Due to contamination because of the avulsion and risk of inflammatory root resorption, systematic antibiotic usage is recommended [20,21].

2.5.6.1.1.1. Extra-Oral Dry Time Less Than 60 Min

If visible contamination is present, flush the root surface with a stream of saline or osmolality-balanced media (HBSS) to eliminate debris. Examine the avulsed tooth for surface debris. Remove any debris by gently agitating it in the storage medium or rinse its surface with a stream of saline. While clinical, radiographic examination keep the tooth in the storage medium. If anesthesia is required, use local anesthesia without a vasoconstrictor. If there is a fracture in the alveolar bone reposition it into the original position. Irrigate the socket with sterile saline and remove coagulation to better reposition of avulsed tooth. With slow digital pressure, replant the avulsed tooth into its original position. Check the position of tooth clinically and radiographically. The tooth should be stabilized with a passive, non-rigid splint for 2-week. If there is an alveolar bone fracture present, a more rigid splint for 4-week is recommended. RCT should be initiated within 2-week after replantation [1,3,20,21].

2.5.6.1.1.2. Extra-Oral Dry Time Longer Than 60 Min

Remove debris and contamination on the root surface and keep the avulsed tooth in the storage media for clinical and radiographic examination. Preferably apply local anesthesia without vasoconstrictor. Clean the socket with saline and check the alveolar bone for any fracture. Replant the avulsed tooth with slight digital pressure and verify it both clinically and radiographically. Stabilize the tooth with a non-rigid, flexible splint for 2-week, if an alveolar bone fracture is present this time could extend to 4-week. RCT should initiate within 2-week.

Delayed replantation has an unfavorable long-term prognosis [21,22]. The periodontal ligament becomes necrotic and is not anticipated to regenerate. Thus, the expected outcome is ankylosis (replacement root resorption). The main purpose of replantation is, to restore aesthetics, and function while preserving alveolar bone width and contour. For these purposes, replantation even if the tooth's extra-oral dry time is more than 60 min is a great option. Replantation ensures flexibility for future treatment options. If necessary, the tooth can be extracted at the appropriate time.

2.5.6.2. Treatments for Permanent Teeth with Open Apex

2.5.6.2.1. The Tooth Has Been Replanted at the Site of Injury

Clean the traumatized area with water, saline or CHX. Check the accuracy of replanted tooth clinically and radiographically. If the tooth's position is accurate leave it, if it doesn't make corrections by applying slight pressure. If the tooth needs position correction, do it within 48 h. While correction if anesthesia is required, use local anesthesia without a vasoconstrictor. The tooth should be stabilized with a passive, non-rigid splint for 2-week. For future root development in immature teeth in children, revascularization should be considered. The risk of inflammatory root resorption should be considered. This kind of resorption is fast in children. If spontaneous revascularization does not occur, apexification, revascularization or RCT should be initiated at the time pulp necrosis is identified [21, 23, 24].

In immature teeth with open apices, there is a chance for spontaneous healing with new connective tissue due to vascular supply and this allows root development, and maturation. RCTs should be initiated only when there is a sign of pulp necrosis.

2.5.6.2.1.1. Extra-Oral Dry Time Less Than 60 Min

If visible contamination is present, flush the root surface with a stream of saline or osmolality-balanced media (HBSS) to eliminate debris. Examine the avulsed tooth for surface debris. Remove any debris by gently agitating it in the storage medium or rinse its surface. While clinical, radiographic examination keep the tooth in the storage medium. If anesthesia is required, use local anesthesia without a vasoconstrictor.

If there is a fracture in the alveolar bone reposition it into the original position. Irrigate the socket with sterile saline and remove coagulation to better reposition of avulsed tooth. With slow digital pressure, replant the avulsed tooth into its original position. Check the position of tooth clinically and radiographically. The tooth should be stabilized with a passive, non-rigid splint for 2-week. Alternatively, nylon fishing lines can be used, due to their flexibility. If there is an alveolar bone fracture present, a more rigid splint for 4-week is recommended.

In cases of replanting immature teeth in children, aim for pulp space revascularization to promote further root development. Assess the risk of external infection-related (inflammatory) root resorption against the likelihood of revascularization. Note that such resorption progresses rapidly in children. If spontaneous revascularization does not occur, consider apexification, pulp revitalization/revascularization, or root canal treatment as soon as pulp necrosis and infection are identified [1, 20-22].

2.5.6.2.1.2. Extra-Oral Dry Time Longer Than 60 Min

If visible contamination is present, flush the root surface with a stream of saline or osmolality-balanced media (HBSS) to eliminate debris. Examine the avulsed tooth for surface debris. Remove any debris by gently agitating it in the storage medium or rinse its surface with a stream of saline. While clinical, radiographic examination keep the tooth in the storage medium. If anesthesia is required, use local anesthesia without a vasoconstrictor.

If there is a fracture in the alveolar bone reposition it into the original position. Irrigate the socket with sterile saline and remove coagulation to better reposition of avulsed tooth. With slow digital pressure, replant the avulsed tooth into its original position. Check the position of tooth clinically and radiographically. The tooth should be stabilized with a passive, non-rigid splint for 2-week. If there is an alveolar bone fracture present, a more rigid splint for 4-week is recommended. RCT should initiate within 2-week after replantation.

In cases of replanting immature teeth in children, aim for pulp space revascularization to promote further root development. Assess the risk of external infection-related (inflammatory) root resorption against the likelihood of revascularization. Note that such resorption progresses rapidly in children. If spontaneous revascularization does not occur, consider apexification, pulp revitalization/revascularization, or RCT as soon as pulp necrosis and infection are identified [1, 16, 20-22].

3. Vital Pulp Therapies (VPTs) for TDIs

In the initial 48 h following an TDI, the pulp's initial response is proliferative, characterized by a depth of pulpal inflammation not exceeding 2 mm. Beyond this period, the risk of direct microbial contamination of the pulp rises as the zone of inflammation advances apically [25]. VPT for the inflamed pulp offers a less predictable success rate [26]. Therefore 24 h is the optimal time range for treatment.

3.1. Types of the VPTs

3.1.1. Pulp-capping

Direct pulp-capping is aimed at preserving the vitality of the entire pulp by applying a biomaterial directly onto the exposed tissue [27]. However, direct pulp-capping following trauma is typically recommended for small pulp exposures treated shortly after the injury [28, 29]. Therefore, partial pulpotomy is preferred for most cases, especially if a large area of the pulp is exposed and treatment cannot be performed within the first few hours after the injury [30, 31].

3.1.2. Partial Pulpotomy

Partial pulpotomy is typically performed using a small cylindrical diamond bur in a high-speed handpiece with continuous irrigation. This procedure involves removing approximately 2 mm of the coronal pulp. Similar to direct pulp capping, rinsing the pulp wound cotton wool or sponge pellets soaked in with sodium hypochlorite or CHX is recommended during partial pulpotomy to aid in hemostasis and disinfection [27,32]. If the remaining pulp is reduced to a healthy level, any bleeding is expected to stop within 5 min. If hemostasis has not occurred within this time, the removal of the entire coronal pulp (full pulpotomy) can be considered as a last step to maintain the vitality of the radicular pulp. Partial pulpotomy after trauma is associated with very high success rates, especially in immature teeth (90-100%), but also exhibits high success rates ranging from 70% to 100% in mature teeth [33-35].

3.1.3. Full Pulpotomy

The procedure involves completely removing the coronal pulp tissue, followed by placing a biomaterial directly onto the pulp tissue at the level of the root canal orifices. This is done before the insertion of a permanent restoration [36]. According to a systematic review, the average success rate reported for full pulpotomy was found to be 97.4% clinically and 95.4% radiographically at a 12-month follow-up [37].

3.2. Used Materials in VPTs

The quality and sealing of the filling restoration material is of utmost importance for the success of the sealant and the prognosis of the treatment. In the 1990s, direct pulp-capping sealants with resin-containing materials were reported to give medium- to good-term results [38]. However, the degradation of the material, especially at the tooth-filling joints, was not sufficiently taken into account, leading to acute inflammatory responses with bacterial infiltration or pulpal necrosis several months after treatment [39]. The existence of these conditions has led to significant changes in the procedures for VPTs. Complete biologic sealing of the pulp has come to be accepted as a basic method. In the first phase, this goal was achieved by using materials with bioactive properties. These materials provided the necessary biocompatibility for the preservation and healing of the pulp tissue. Subsequently, new materials were developed to maintain the vitality of the pulp by promoting dentin bridge formation, and these materials have been effectively used in pulp-capping procedures.

For many years, calcium hydroxide (CH) has been used as a pulp-capping material. The direct application of this material to the pulp results in the formation of a mineral barrier; however, this barrier has been found to lack a regular structure, to have multiple tunnel defects and to not form a solid connection with the dentin wall. This prevents a long-term seal. Furthermore, since the CH tends to dissolve over time, it has been observed that after a few months the clinical situation is as if no closure material had been used [40]. In recent years, the use of CH in VPTs has been avoided. Instead, more stable and biocompatible materials are preferred. Recently, calcium silicate-based materials that meet these properties have come to the fore. The American Association of Endodontists also recommends the use of calcium silicate-based cements, which have been found to be successful in clinical practice in VPTs [41]. These are a class of materials that includes tricalcium silicates, dicalcium silicates, hydraulic calcium silicate cements and biological ceramic materials.

As a result, CH remains a commonly used pulp-capping material, known for its high success rates [30], despite its mechanical instability and gradual dissolution over time [42]. Calcium silicate-based cements address the issue of mechanical instability while providing excellent biological properties. However, some of these materials may have a drawback related to their potential for discoloration, which can be caused by the presence of radiopacifiers and the absorption of blood components within the material [43,44].

4. Regenerative Endodontic Treatment (RET) and TDIs

RET is a biologic-based treatment modality for immature permanent teeth diagnosed with pulp necrosis and/or apical periodontitis/abscess and is also advocated for mature teeth with necrotic pulps. It regenerated the pulp-dentine complex that has been damaged by infection and/or trauma. RET utilizes the triage of tissue engineering concepts of stem cells, bioactive materials that can act as scaffolds and growth factors to provide the micro-environment for regeneration and repair. It focuses on repairing pulp tissue and stimulating dentin production in the root canal system, effectively allowing the tooth to heal and develop more fully. This contrasts with traditional RCT, which often entails removing the pulp tissue and filling the root canal with permanent filling material. The ultimate goal is to regenerate a functional pulp-dentin complex and regain the immune competency and normal nociception [45-47].

The first studies on RET in traumatized teeth were published in 2008 [48,49]. When the articles published later are analyzed, they provide optimism for the use of RET in trauma cases. However, treating immature teeth, particularly after avulsion and replantation, continues to be a therapeutic challenge, sometimes with unsatisfactory results. More cases with long-term follow-up on this topic should be done.

Conclusion

As in every field, there are also current changes in the selected treatment protocols and materials used in dental traumatology. There are scientific organizations like IADT or journals that publish important and specialized research on this topic. Following these resources will be a great guide for clinicians. In this compilation, the updates made by these sources have been brought together to inform clinicians or researchers.

REFERENCES

1 Bourguignon C, Cohenca N, Lauridsen E, Flores MT, O'Connell AC, Day PF, Tsilingaridis G, Abbott PV, Fouad AF, Hicks L, Andreasen JO, Cehreli Z, Harlamb S, Kahler B, Oginni A, Semper M, Levin L. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 1. Fractures and luxations. Dent Traumatol. 2020; 36: 314-30. DOI: 10.1111/edt.12578

2 Rozi AH, Scott JM, Seminario AL. Trauma in permanent teeth: factors associated with adverse outcomes in a university pediatric dental clinic. J Dent Child (Chic). 2017; 84: 9-15.

3 Levin L, Day PF, Hicks L, O'Connell A, Fouad AF, Bourguignon C, Abbott PV. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: general introduction. Dent Traumatol. 2020; 36: 309-13. DOI:10.1111/edt.12574

4 Krastl G, Weiger R, Ebeleseder K, Galler K. Present status and future directions: endodontic management of traumatic injuries to permanent teeth. Int Endod J. 2022; 55: 1003-19. DOI: 10.1111/iej.13672

5 Bastos JV, Goulart EMA, de Souza Côrtes MI. Pulpal response to sensibility tests after traumatic dental injuries in permanent teeth. Dent Traumatol. 2014; 30: 188-92. DOI: 10.1111/edt.12074

6 Cohenca N, Silberman A. Contemporary imaging for the diagnosis and treatment of traumatic dental injuries: a review. Dent Traumatol. 2017; 33: 321-8. DOI: 10.1111/edt.12339

7 Jafarzadeh H, Abbott PV. Review of pulp sensibility tests. Part I: general information and thermal tests. Int Endod J. 2010; 43: 738-62. DOI: 10.1111/j.1365-2591.2010.01754.x

8 Schendel KU, Schwartz O, Andreasen JO, Hoffmeister B. Reinnervation of autotransplanted teeth. A histological investigation in monkeys. Int J Oral Maxillofac Surg. 1990; 19: 247-9. DOI: 10.1016/s0901-5027(05)80403-5

9 Gopikrishna V, Tinagupta K, Kandaswamy D. Evaluation of efficacy of a new custom-made pulse oximeter dental probe in comparison with the electrical and thermal tests for assessing pulp vitality. J Endod. 2007; 33: 411-4. DOI: 10.1016/j.joen.2006.12.003

10 Gopikrishna V, Tinagupta K, Kandaswamy D. Comparison of electrical, thermal, and pulse oximetry methods for assessing pulp vitality in recently traumatized teeth. J Endod. 2007; 33: 531-5. DOI: 10.1016/j.joen.2007.01.014

11 Karayilmaz H, Kirzioğlu Z. Comparison of the reliability of laser Doppler flowmetry, pulse oximetry and electric pulp tester in assessing the pulp vitality of human teeth. J Oral Rehabil. 2011; 38: 340-7. DOI: 10.1111/j.1365-2842.2010.02160.x

12 Polat S, Er K, Akpinar KE, Polat NT. The sources of laser Doppler blood-flow signals recorded from vital and root canal treated teeth. Arch Oral Biol. 2004; 49: 53-7. DOI: 10.1016/s0003-9969(03)00197-3
13 Akpinar KE, Er K, Polat S, Polat NT. Effect of gingiva on laser Doppler pulpal blood flow measurements. J Endod. 2004; 30: 138-40. DOI: 10.1097/00004770-200403000-00003
14 Polat S, Er K, Polat NT. Penetration depth of laser Doppler flowmetry beam in teeth. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 2005; 100: 125-9. DOI: 10.1016/j.tripleo.2004.11.018
15 Polat S, Er K, Polat NT. The lamp effect of laser Doppler flowmetry on teeth. J Oral Rehabil. 2005; 32: 844-8. DOI: 10.1111/j.1365-2842.2005.01510.x
16 Andreasen JO, Andreasen FM, Andersson L. Textbook and color atlas of traumatic injuries to the teeth. John Wiley & Sons; 2018.
17 Wang G, Wang C, Qin M. A retrospective study of survival of 196 replanted permanent teeth in children. Dent Traumatol. 2019; 35: 251-8. DOI: 10.1111/edt.12475
18 Arda Sözüöz M, Aksoy M. Replantation of an avulsed matur permanent upper incisor: a case report. Akd Dent J. 2024; 3: 81-7. DOI: 10.62268/add.1254467
19 Barbizam JVB, Massarwa R, da Silva LAB, da Silva RAB, Nelson-Filho P, Consolaro A, Cohenca N. Histopathological evaluation of the effects of variable extraoral dry times and enamel matrix proteins (enamel matrix derivatives) application on replanted dogs' teeth. Dent Traumatol. 2015; 31: 29-34. DOI: 10.1111/edt.12131
20 Sae-Lim V, Wang CY, Choi GW, Trope M. The effect of systemic tetracycline on resorption of dried replanted dogs' teeth. Endod Dent Traumatol. 1998; 14: 127-32. DOI: 10.1111/j.1600-9657.1998.tb00825.x
21 Fouad AF, Abbott PV, Tsilingaridis G. International Association of Dental Traumatology guidelines for the management of traumatic dental injuries: 2. Avulsion of permanent teeth. Dent Traumatol. 2020; 36: 331-342. DOI: 10.1111/edt.12573
22 Malmgren B, Malmgren O. Rate of infraposition of reimplanted ankylosed incisors related to age and growth in children and adolescents. Dent Traumatol. 2002; 18: 28-36. DOI: 10.1034/j.1600-9657.2002.180104.x
23 Kahler B, Rossi-Fedele G, Chugal N, Lin LM. An evidence-based review of the efficacy of treatment approaches for immature permanent teeth with pulp necrosis. J Endod. 2017; 43: 1052-7. DOI: 10.1016/j.joen.2017.03.003
24 Kim SG, Malek M, Sigurdsson A, Lin LM, Kahler B. Regenerative endodontics: a comprehensive review. Int Endod J. 2018; 51: 1367-88. DOI: 10.1111/iej.12954
25 Cvek M, Hollender L, Nord CE. Treatment of non-vital permanent incisors with calcium hydroxide. VI. A clinical, microbiological and radiological evaluation of treatment in one sitting of teeth with mature or immature root. Odontol Revy. 1976; 27: 93-108. DOI:
26 Swift Jr EJ, Trope M. Treatment options for the exposed vital pulp. Pract Periodontics Aesthet Dent. 1999; 11(6): 735-9.
27 Duncan HF, Galler KM, Tomson PL, Simon S, El-Karim I, Kundzina R, Krastl G, Dammaschke T, Fransson H, Markvart M, Zehnder M, Bjørndal L. European Society of Endodontology position statement: management of deep caries and the exposed pulp. Int Endod J. 2019; 52(7): 923-34. DOI: 10.1111/iej.13080
28 Cvek M. A clinical report on partial pulpotomy and capping with calcium hydroxide in permanent incisors with complicated crown fracture. J Endod. 1978; 4: 232-7. DOI: 10.1016/S0099-2399(78)80153-8
29 Krastl G, Weiger R. Vital pulp therapy after trauma. Endo (Lond Engl). 2014; 8: 1-8.
30 Dammaschke T, Galler K, Krastl G. Current recommendations for vital pulp treatment. Dtsch Zahnärztl Z Int. 2019; 1: 43-52.
31 Krastl G, Filippi A, Weiger R. Initial management of dental trauma: musts, shoulds, and cans. Quintessence Int (Berl). 2020; 51: 763-74. DOI: 10.3290/j.qi.a45103
32 Munir A, Zehnder M, Rechenberg DK. Wound lavage in studies on vital pulp therapy of permanent teeth with carious exposures: a qualitative systematic review. J Clin Med. 2020; 9: 984. DOI: 10.3390/jcm9040984

33 de Blanco LP. Treatment of crown fractures with pulp exposure. Oral Surg Oral Med Oral Pathol Oral Radiol Endod. 1996; 82: 564-8. DOI: 10.1016/s1079-2104(96)80204-6
34 Hecova H, Tzigkounakis V, Merglova V, Netolicky J. A retrospective study of 889 injured permanent teeth. Dent Traumatol. 2010; 26: 466-75. DOI: 10.1111/j.1600-9657.2010.00924.x
35 Wang G, Wang C, Qin M. Pulp prognosis following conservative pulp treatment in teeth with complicated crown fractures-a retrospective study. Dent Traumatol. 2017; 33: 255-60. DOI: 10.1111/edt.12332
36 Kumar V, Chawla A, Priya H, Sachdeva A, Sharma S, Kumar V, Logani A. Comparative evaluation of full and partial pulpotomy in permanent teeth with irreversible pulpitis: a systematic review and meta-analysis. Aust Endod J. 2024; 50: 388-96. DOI: 10.1111/aej.12844
37 Cushley S, Duncan HF, Lappin MJ, Tomson PL, Lundy FT, Cooper P, Clarke M, El Karim IA. Pulpotomy for mature carious teeth with symptoms of irreversible pulpitis: a systematic review. J Dent. 2019; 88: 103158. DOI: 10.1016/j.jdent.2019.06.005
38 Cox CF, Hafez AA, Akimoto N, Otsuki M, Suzuki S, Tarim B. Biocompatibility of primer, adhesive and resin composite systems on non-exposed and exposed pulps of non-human primate teeth. Am J Dent. 1998; 11: S55-63.
39 Nair PNR, Duncan HF, Pitt Ford TR, Luder HU. Histological, ultrastructural and quantitative investigations on the response of healthy human pulps to experimental capping with mineral trioxide aggregate: a randomized controlled trial. Int Endod J. 2008; 4: 128-50. DOI: 10.1111/j.1365-2591.2007.01329.x
40 Njeh A, Uzunoğlu E, Ardila-Osorio H, Simon S, Berdal A, Kellermann O, Goldberg M. Reactionary and reparative dentin formation after pulp capping: Hydrogel vs. Dycal. Evid-Based Endod. 2016; 1: 3. DOI: 10.1186/s41121-016-0003-9
41 AAE Position Statement on Vital Pulp Therapy. J Endod. 2021; 47: 1340-4. DOI: 10.1016/j.joen.2021.07.015
42 Bakland LK, Andreasen JO. Will mineral trioxide aggregate replace calcium hydroxide in treating pulpal and periodontal healing complications subsequent to dental trauma? A review. Dent Traumatol. 2012; 28: 25-32. DOI: 10.1111/j.1600-9657.2011.01049.x
43 Lenherr P, Allgayer N, Weiger R, Filippi A, Attin T, Krastl G. Tooth discoloration induced by endodontic materials: a laboratory study. Int Endod J. 2012; 45: 942-9. DOI: 10.1111/j.1365-2591.2012.02053.x
44 Krastl G, Allgayer N, Lenherr P, Filippi A, Taneja P, Weiger R. Tooth discoloration induced by endodontic materials: a literature review. Dent Traumatol. 2013; 29: 2-7. DOI: 10.1111/j.1600-9657.2012.01141.x
45 Wei X, Yang M, Yue L, Huang D, Zhou X, Wang X, Zhang Q, Qiu L, Huang Z, Wang H, Meng L, Li H, Chen W, Zou X, Ling J. Expert consensus on regenerative endodontic procedures. Int J Oral Sci. 2022; 14: 55. DOI: 10.1038/s41368-022-00206-z
46 Kim SG, Malek M, Sigurdsson A, Lin LM, Kahler B. Regenerative endodontics: a comprehensive review. Int Endod J. 2018; 51: 1367-1388. DOI: 10.1111/iej.12954
47 Kahler B, Lu J, Taha NA. Regenerative endodontic treatment and traumatic dental injuries. Dent Traumatol. 2024; 40: 618-635. DOI: 10.1111/edt.12979
48 Cotti E, Mereu M, Lusso D. Regenerative treatment of an immature, traumatized tooth with apical periodontitis: report of a case. J Endod. 2008; 34: 611-6. DOI: 10.1016/j.joen.2008.02.029
49 Shah N, Logani A, Bhaskar U, Aggarwal V. Efficacy of revascularization to induce apexification/apexogensis in infected, nonvital, immature teeth: a pilot clinical study. J Endod. 2008; 34: 919-25. DOI: 10.1016/j.joen.2008.05.001

Ethics Committee Approval: No need.
Conflict of Interest: The authors declared no conflict of interest.
Financial Disclosure: Authors declare that they have no funding.
Orchid IDs: Dide Tekinarslan: 0000-0002-7818-4992; Kürşat Er: 0000-0002-0667-4909
Author Contribution: Planning of design and study process – KE, DT; Literature review – DT, KE; Critical language revision - KE; and writing – DT, KE.
Correspondence: Prof. Dr. Kürşat Er, Department of Endodontics, Faculty of Dentistry, Akdeniz University, Antalya, Turkiye. tel. +90 (505) 6542725, fax: +90 (242) 3106967, e-mail. mkursater@gmail.com

The authors state that the material contained in the manuscript is original, has not been previously published and is not being concurrently submitted elsewhere. All authors have read and approved the manuscript.

Correspondence: Prof. Dr. Kürşat Er, Department of Endodontics, Faculty of Dentistry, Akdeniz University, Antalya, Turkiye. tel. +90 (505) 6542725, fax: +90 (242) 3106967, e-mail. mkursater@gmail.com