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Evaluations in the Field of

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Research And Evaluations In The Field Of Endodontics

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İÇİNDEKİLER

CHAPTER 1

REGENERATIVE ENDODONTICS

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1. INTRODUCTION

1.1 Introduction to Regenerative Endodontics

Each year, millions of teeth are preserved through root canal treatment. While existing treatments are generally successful, a potentially better therapeutic approach might involve the replacement of necrotic pulp tissue with healthy pulp tissue to restore vitality to the tooth (Murray et al., 2007).

Traditionally, non-vital infected teeth have been treated with root canal therapy (for mature apices) or apexification (for immature apices) or have ultimately been extracted. While these treatments are effective in alleviating symptoms and eliminating infection, they fail to regenerate healthy pulp tissue. But what if a non-vital tooth could be revitalized? This concept represents the promise offered by regenerative endodontics a novel field focused on replacing traumatized or diseased pulp with functional, living pulp tissue (Bansal et al., 2011).

2. What is Regenerative Endodontics?

Regenerative endodontics refers to the invention and development of new tissue to revitalize damaged, deficient, or compromised pulp. Root development is typically completed within three years after tooth eruption into the oral cavity (Moorrees et al., 1963). Pulp necrosis caused by trauma, caries, or dental anomalies can be the cause of this development. The goal of this treatment is to re-establish the components of pulp-dentin complex and maintain healthy tooth structure in order to prolong the tooth's lifespan and maintain its functionality (Murray et al., 2007).

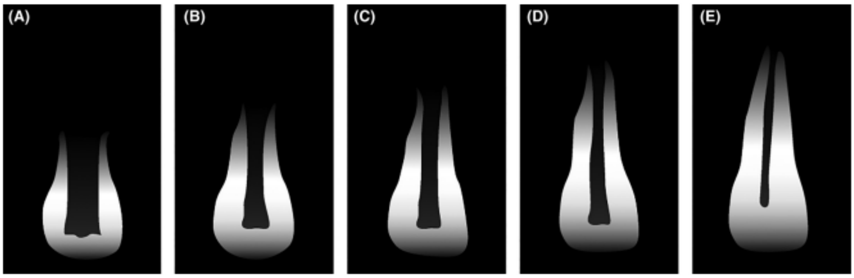
The success criteria of regenerative treatment include resolution of symptoms, periapical bone healing, continued root development in terms of increased thickness and length (an advantage over apexification), and the restoration of pulp vitality (Diogenes et al., 2013; Kaval et al., 2018; Sakai et al., 2010). If no signs of root development are detected within three months following treatment, the clinician should consider switching to an apexification protocol (Murray et al., 2007; Siu-Fai, 2010).

2.1 Tissue Engineering

Recently, there has been an increasing pursuit of therapeutic strategies aimed at supporting the innate regenerative potential of damaged tissues and restoring their morphological and functional integrity. Accordingly, tissue engineering is shining in reconstructive surgical procedures, particularly for the repair of bone defects that lack spontaneous regenerative capacity as an alternative (Cheng et al., 2013).

Tissue engineering relies on the interaction of stem cells, growth factors, and scaffolds (biological matrices) (d'Aquino et al., 2009).

2.2 Cvek's (1992) Root Canal Classification



Four distinct radiographic stages of root development can be observed.

- Figure A represents an absence of root development.
- Figure B shows closure of the apical foramen without any increase in root length or thickness.
- Figure C indicates root wall thickening while the apex remains open.
- Figure D presents both root thickening and apical closure.
- Figure E refers to a fully mature tooth.

Among these, Figures D and E are associated with the most favorable outcomes for regenerative endodontic treatment (Kahler, Lu, & Taha, 2024; Van Gorp & Declerck, 2023).

3. Stem Cells

Stem cells are defined as undifferentiated cells possessing the capability to self-renew and differentiate into the cell types derived from their original tissue. They are characterized as either pluripotent or multipotent. Pluripotent stem cells can differentiate into cell types derived from all three germ layers; embryonic stem cells are a prime example of pluripotent cells. Adult mesenchymal stem cells (MSCs), on the other hand, have a limited differentiation range, being able to generate only mesenchyme-derived tissues, and are thus categorized as multipotent.

Stem cells from the apical papilla (SCAPs) represent a packed source of undifferentiated MSCs with odontogenic differentiation capacity and are initially responsible for root formation throughout the process of tooth development. The proximity of the apical papilla to the root canal space provides this rich source of stem cells readily accessible for regenerative endodontic procedures.

Inflamed periapical apical papilla-derived cells (iPAPCs) also represent an important potential stem cell source for regenerative endodontics in teeth affected by apical periodontitis. These cells have predominantly been found localized around blood vessels within apical granulomatous tissue. Remarkably, even in teeth with advanced apical periodontitis or apical abscess, a high number of MSCs have been detected within the root canal space after inducing apical bleeding. This suggests a superior survival capacity of these cells.

The biological basis for this resilience may lie in the relatively low vascular density of the apical papilla compared to adjacent dental pulp, combined with the high vascularization of the surrounding dental follicle. The follicle also provides essential nutritional support to SCAPs (Driesen et al., 2021).

4. Growth Factors

Dentin consists primarily of collagen fibers (approximately 90%, predominantly type I collagen) and non-collagenous matrix molecules such as proteoglycans, phosphoproteins, and phospholipids. Collagen fibers serve as a scaffold or framework within which mineralization occurs. Among the non-collagenous proteins specific to dentin, dentin phosphoprotein (DPP) and dentin sialoprotein (DSP) are the most abundant. DSP is thought to play a role in matrix mineralization (Butler et al., 1998).

Another critical element for root regeneration is growth factors, which are signaling proteins that regulate cellular proliferation, differentiation, and maturation. Dentin is known to act as a primary reservoir of such signaling molecules. It is hypothesized that growth factors and cytokines become embedded in dentin during the process of mineralization. These bioactive molecules can be released through various techniques, including the use of EDTA, calcium hydroxide, or acid etching (Kontakiotis et al., 2015; Bègue-Kirn et al., 1992).

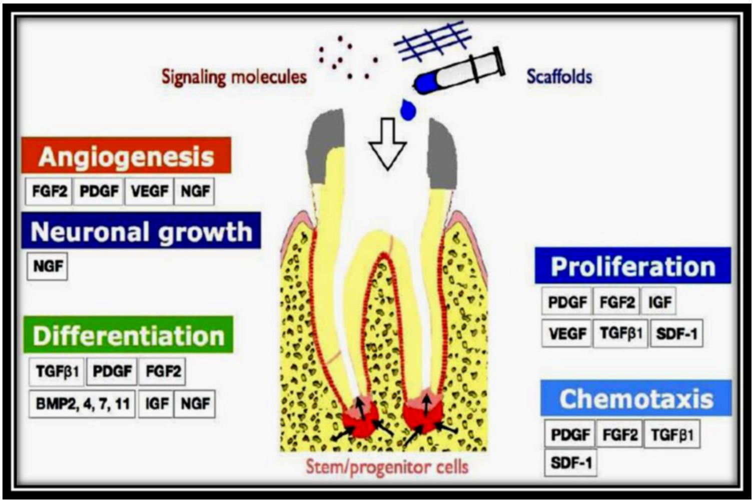


Figure Growth factors in the dental region

Transforming Growth Factor Beta 1 (TGF-β1) plays a key role in regulating both the inflammatory response and tissue regenerative processes. TGF-β1 is one of the most throughly researched bioactive molecules, known to promote cell proliferation, differentiation, and chemotaxis across a variety of cell types. Therefore, it is considered a fundamental molecule in pulp regeneration (Niwa, 2018).

Bone Morphogenetic Protein 2 (BMP-2), a member of the BMP subgroup within the TGF-β superfamily, plays a central role in embryonic dorsal–ventral patterning, organogenesis, limb bud formation, and bone development and regeneration. BMP-2 is a cytokine capable which has a great capacity of inducing bone and cartilage formation when combined with osteoconductive carriers such as collagen and synthetic hydroxyapatite (Merck Millipore, n.d.).

Insulin-like Growth Factor 1 (IGF-1), an essential anabolic hormone, regulates key biological processes including cell metabolism, growth, proliferation, and programmed cell death (Liu et al., 2022).

Vascular Endothelial Growth Factor (VEGF) is a signaling protein formed by cells that activates vasculogenesis and angiogenesis. It is categorized as a vascular growth factor and plays a fundamental role in generating new blood vessels.

4.1 Factors That Induce the Release of Growth Factors from Dentin

Irrigation of dentin with EDTA solution leads to the demineralization of dentin and the subsequent release of growth factors and proteins embedded within the matrix.

Etching with phosphoric acid during bonding procedures causes dentin demineralization and the liberation of biologically active molecules, including growth factors.

Calcium hydroxide has been shown to emit bioactive components from dentin, such as growth factors. Its effect is known to be long-lasting.

Application of MTA or Biodentine results in the formation of calcium hydroxide as a byproduct, which indirectly promotes the release of dentin-derived growth factors.

Bacterial acids can demineralize dentin, leading to the release of growth factors as part of the carious process.

Irrigation with maleic acid has also been reported to induce the release of dentin growth factors (Ballal et al., 2022).

5. Scaffolds

Tissues are organized as three-dimensional structures, which are essential for the spatial positioning of cells and for regulating differentiation, proliferation, or metabolism by facilitating nutrient and gas exchange. Scaffolds are much more than simple frameworks containing cells; they can be considered as a biological "template" for tissue development. Scaffolds can be categorized as either natural or synthetic in origin.

In the majority of published regenerative studies, apical bleeding has been intentionally induced, and the resulting blood clot within the root canal has served as a scaffold. However, obtaining a stable blood clot is not always straightforward, and the clot itself lacks several ideal properties expected from a scaffold. These include ease of handling, adequate mechanical strength, controllable biodegradability, and the ability to incorporate growth factors.

Moreover, a blood clot includes a high number of hematopoietic cells, which ultimately experience cell apoptosis and release intracellular enzymes into the microenvironment. These enzymes could become toxic and potentially detrimental to stem cell survival over time (Liu et al., 2022).

Natural Scaffolds	Synthetic Scaffolds
Collagen Glycosaminoglycans (GAGs) Hyaluronic acid (HA) Platelet-Rich Plasma (PRP) Platelet-Rich Fibrin (PRF) Demineralized or native dentin Fibrin Blood clot	Polylactic acid (PLA) Polyglycolic acid (PGA) Polylactic-co-glycolic acid (PLGA) Poly-ε-caprolactone (PCL) Polyethylene glycol (PEG) Hydroxyapatite (HA) Bioceramics Hydrogels Titanium Alginate

5.1 PRP and PRF

Platelet-Rich Plasma (PRP) is rich in growth factors; however, it tends to degrade over time. Platelet-Rich Fibrin (PRF) has emerged as a replacement to PRP due to its three-dimensional architecture that supports stem cell proliferation and differentiation, as well as its content of bioactive molecules. These autologous scaffolds have proven successful in regenerative treatments.

Nevertheless, they present certain disadvantages. Both require intravenous blood collection, which can be challenging, particularly in pediatric patients. Moreover, the type and content of growth factors contained within PRP or PRF cannot be precisely controlled. Their biological degradation rates are unpredictable, and they do not offer sufficient mechanical support to aid in coronal restoration (Buzoğlu, n.d.).

5.2 Hydrogels

Hydrogels are a type of scaffold material made up of three-dimensional, water-attracting polymers capable of absorbing fluids several times their own weight. These water-swollen materials can be swiftly injected in colloidal forms that undergo gelation in response to chemical stimuli (e.g., changes in pH or osmolarity) and/or physical stimuli (e.g., changes in temperature).

Hydrogels are highly biocompatible and customizable materials, capable of being engineered to mimic the natural extracellular matrix (ECM). They can readily be delivered into narrow root canal spaces through injection. Furthermore, hydrogels can be functionalized with chemotactic and angiogenic agents to promote the recruitment of stem cells and enhance angiogenesis within the root canal space (Diogenes et al., 2013; Gonzalez-Ramos et al., 2013).

6. CLINICAL PROCEDURES IN REGENERATIVE ENDODONTICS

Clinicians often encounter numerous challenges when managing teeth with open apices. Cleaning and shaping of the apical portion can be difficult, and due to the presence of thin and fragile dentinal walls, there is a high risk of root fracture during instrumentation or obturation. Additionally, open apices increase the risk of extrusion of materials into the periradicular tissues. Traditionally, immature teeth with open apices have been treated with apexification, aiming to create an apical barrier to prevent overextension of materials. In most cases, a hard tissue barrier is formed apically after long-term treatment with calcium hydroxide ($Ca(OH)_2$).

However, a significant drawback of conventional apexification procedures is the potential of $Ca(OH)_2$, whether used short- or long-term, to reduce the fracture resistance of the root structure. Moreover, these techniques generally do not support continued root development (Cvek, 1972; Cvek, 1992).

6.1 Triple Antibiotic Paste (TAP)

Researchers and clinicians have used various intracanal medicaments for disinfecting the root canal space. In 51%–80% of clinical cases, Triple Antibiotic Paste (TAP) a 1:1:1 combination of ciprofloxacin, metronidazole, and minocycline is used, whereas calcium hydroxide is used in approximately 20%–37% of cases. TAP possesses both bactericidal (ciprofloxacin and metronidazole) and bacteriostatic (minocycline) properties.

Metronidazole is a broad-spectrum antibiotic effective against anaerobic bacteria, minocycline is a tetracycline derivative, and ciprofloxacin is a bactericidal fluoroquinolone antibiotic (Sabrah et al., 2020).

In an animal study conducted by Windley et al., the combination of ciprofloxacin, metronidazole, and minocycline (TAP) achieved effective disinfection in immature permanent teeth with apical periodontitis in dogs. The 3-mix antibiotic formulation demonstrated potent antibacterial activity, particularly against E. faecalis and E. faecium. TAP has been shown to eliminate endodontic pathogens, facilitate healing of large periapical lesions, and suppress microbial factors that inhibit vital tissue ingrowth in immature teeth with periapical periodontitis (Parasuraman & Muljibhai, 2012; Windley et al., 2005).

Advantages

- Effectively eliminates bacteria at high concentrations and creates a favorable environment for regeneration.
- Has been shown to increase dentin thickness more than other intracanal medicaments.

Disadvantages

- May lead to the development of antibiotic resistance.
- Its acidic nature can alter the chemical properties of radicular dentin.
- Exhibits cytotoxic effects on stem cells.
- Minocycline can cause tooth discoloration.
- It is challenging to remove from the root canal once applied.

6.1.1 Minocycline

Minocycline is a tetracycline-derived, bacteriostatic antibiotic. It has been reported that minocycline, included in Triple Antibiotic Paste (TAP), can cause tooth discoloration within as **little** as six weeks. Consequently, alternative antibiotics that have been shown to cause less discoloration such as amoxicillin, cefaclor, cefroxadine, fosfomycin, and rokitamycin have recently been proposed for use.

Minocycline, as a tetracycline derivative, can promote host cell proliferation within dentin not solely through its antimicrobial action, but also by inducing the release of collagen fibrils or growth factors (Simon et al., 2007). It exhibits high affinity for lipids (Naline et al., 1991). Its mechanism of action involves binding to the 30S ribosomal subunit of bacteria, thereby inhibiting protein synthesis, similar to other tetracyclines. Several studies have reported high sensitivity of *Staphylococcus aureus* strains to minocycline (Vuve, 1988; Yuk et al., 1991; Clumeck et al., 1984).

6.1.2 Ciprofloxacin

Ciprofloxacin is an antibiotic used to combat various bacterial infections. As a member of the fluoroquinolone group, it acts by inhibiting bacterial DNA gyrase, thereby interfering with DNA replication. Ciprofloxacin has demonstrated stronger in vitro antibacterial activity against various bacterial strains compared to other quinolones (Neu, 1988). Among quinolones, ciprofloxacin and ofloxacin are considered the most active against Gram-positive bacteria (Walker & Wright, 1987).

6.1.3 Metronidazole

Metronidazole has become widely used in dental practice due to its high efficacy against anaerobic microorganisms and its ability to penetrate gingival crevicular fluid. It has been shown to exhibit bactericidal effects against obligate anaerobes in the oral cavity and to be effective against bacteria isolated from teeth with infected necrotic pulps (Bansal & Jain, 2014).

However, under in vitro conditions, metronidazole alone at concentrations of 10 µg/ml did not result in healing of infected root dentin, and even at 100 µg/ml, it was insufficient to eliminate all bacteria (Hoshino et al., 1990). Therefore, it is generally used in combination with ciprofloxacin and minocycline for the sterilization of infected root dentin (Hoshino et al., 1996).

6.2 Double Antibiotic Paste (DAP)

Due to the crown discoloration caused by minocycline, clinicians have sought alternative intracanal medicaments. Removal of minocycline from the traditional TAP formulation led to the development of Double Antibiotic Paste (DAP), composed of ciprofloxacin and metronidazole in a 1:1 ratio.

Sato et al. (1996) suggested that minocycline should be used only for limited periods and recommended the substitution of minocycline in TAP to reduce the risk of tooth discoloration.

Montero-Miralles et al. (2018) emphasized that DAP does not cause discoloration and thus serves as a good alternative to TAP in regenerative endodontic treatments. In a study by Ruparel et al. (2012), the survival rates of stem cells from the apical papilla (SCAPs) treated with TAP and DAP were evaluated, with both groups showing comparable results, lacking any significant statistical difference.

6.3 Mineral Trioxide Aggregate (MTA)

When mixed with water, Mineral Trioxide Aggregate (MTA) forms a colloidal gel that sets in approximately 3 hours (Torabinejad et al., 1995). Although the full setting reaction takes longer than 24 hours, the setting process is not affected by the presence of moisture or blood (Chong et al., 2003; Sluyk et al., 1998). The favorable sealing ability of MTA has been attributed to its slight expansion during setting and its antimicrobial properties (Nakata et al., 1998; Fischer et al., 1998).

6.4 Biodentine

Biodentine is a calcium silicate-based material that sets more rapidly than MTA. Its shortened setting time has been attributed to increased particle size, the inclusion of calcium chloride to the liquid component, and a reduction in liquid content. The setting time is reported to be less than 9–12 minutes, which is considered a major advantage over other calcium silicate-based materials (Perez et al., 2003).

6.5 Calcium Hydroxide

Calcium hydroxide is an intracanal medicament used either alone or in combination with antibiotics or other antibacterial agents for disinfection and regeneration in immature teeth (Siqueira & Jr, 1999). It is widely preferred due to its strong antibacterial effect and high alkaline pH. When in direct contact with living tissues, calcium hydroxide can induce the formation of a calcified barrier.

However, its role in persistent periapical infections remains controversial. In cases of chronic bacterial infections, bacteria residing in dentin tubules may buffer the high pH induced by calcium hydroxide, thereby diminishing its antimicrobial effectiveness. Long-term application (longer than one month), especially in teeth with open apices, may increase susceptibility to reinfection in areas exposed to tissue fluids and reduce fracture resistance of the tooth (Andreasen et al., 2002).

Rather than using calcium hydroxide alone, combining it with other antibacterial agents may yield improved outcomes. One study reported that a combination of calcium hydroxide with ciprofloxacin and metronidazole was more effective against *S. aureus*, *P. aeruginosa*, *E. faecalis*, and *B. fragilis* when compared to other combinations such as calcium hydroxide with potassium iodide-iodine or iodoform. These findings suggest that such combinations may be more suitable for infected root canals with mixed bacterial flora (Pallotta et al., 2007).

7. IRRIGATION AGENTS USED IN REGENERATIVE ENDODONTIC TREATMENT

7.1 EDTA

Ethylenediaminetetraacetic acid (EDTA) is one of the most commonly used chelating agents to eliminate the smear layer from the walls of the root canal (Grawehr et al., 2003). As a chelator, EDTA decalcifies the surface of root canal dentin and exposes collagen fibrils (Galler et al., 2011). Decalcification of dentin provides adhesion motifs for newly recruited cells and promotes the release of growth factors that stimulate differentiation into odontoblast-like cells.

While EDTA promotes favorable conditions for cell adhesion and differentiation, it is not effective alone in removing the smear layer. Therefore, it is typically used in combination with sodium hypochlorite (NaOCl) to achieve effective smear layer removal (Goldman et al., 1976).

7.2 Sodium Hypochlorite (NaOCl)

Sodium hypochlorite (NaOCl) is among the most widely used irrigation solutions in root canal treatment due to its numerous clinical advantages. One of its most desirable properties is its ability to dissolve pulp tissue during endodontic procedures. This tissue-dissolving capacity is attributed to its free chlorine content, which is considered responsible for its action on soft tissues (Moorer & Wesselink, 1982; Retamozo et al., 2010).

NaOCl is particularly effective in dissolving organic debris in the root canal. However, the inorganic components of the smear layer can only be removed by chelating or acidic agents with decalcifying properties. Therefore, to enhance antimicrobial activity and ensure effective smear layer removal, the combined use of NaOCl with demineralizing agents such as EDTA is recommended (Lottanti et al., 2009).

However, the most commonly used agent for this purpose, EDTA, has been shown to reduce the amount of free chlorine when used in combination with NaOCl, thereby diminishing the tissue-dissolving and antimicrobial effects of NaOCl (Grawehr et al., 2003; Zehnder et al., 2005).

7.3 Maleic Acid

Maleic acid (MA) at 7% concentration is a chelating agent known for its superior smear layer removal ability compared to 17% EDTA, in both straight and curved root canals (Ballal, 2009; Ulusoy, 2013; Rao, 2021). In comparison to 17% EDTA, 7% MA also increases the surface roughness of intraradicular dentin, which aids in better adhesion of obturation materials (Ballal, 2010). Additionally, it has been shown to be less cytotoxic and more effective in demineralization than EDTA.

8. REGENERATION PROTOCOL

The techniques used in regenerative endodontics can be categorized as: stem cell therapy, root canal revascularization, pulp implantation, scaffold implantation, injectable scaffold applications, three-dimensional cell printing, and gene therapy.

8.1 First Appointment

At the first appointment, after gathering clinical findings and establishing pulpal and periapical diagnoses, treatment options, potential risks, and expected benefits must be clearly explained to the patient and/or guardian (Diogenes et al., 2013).

After administering local anesthesia, the tooth is isolated and an access cavity is prepared. Minimal instrumentation is preferred, with gentle circumferential brushing using Hedström files, avoiding excessive dentin removal. A working length film is then taken using an adequate file.

The canal is then thoroughly irrigated slowly and in large volume. Sodium hypochlorite (NaOCl) is the preferred irrigant in revascularization case reports due to its proven antimicrobial efficacy and tissue-dissolving ability. However, studies have shown that NaOCl-treated dentin can have indirect cytotoxic effects on stem cells. Usege of 1.5% NaOCl followed by 17% EDTA has been shown to mitigate these adverse effects. Therefore, for regenerative endodontic procedures, the standard irrigation protocol involves low-concentration NaOCl (1.5%) followed by EDTA.

The use of chlorhexidine should be limited or avoided, as it does not dissolve tissue and is cytotoxic to stem cells.

Ultrasonic activation of irrigants has been found to improve growth factor release from dentin surfaces and enhance tissue dissolution.

After irrigation, the root canal is dried with sterile paper points, and an intracanal medicament is placed. Current evidence supports the use of either Triple or Double Antibiotic Paste (at 1/10 mg/mL) or calcium hydroxide ($Ca(OH)_2$) as intracanal medicaments. Both have demonstrated efficacy.

TAP offers the advantage of being highly effective against endodontic pathogens, supported by multiple case reports. However, this combination is not FDA-approved, and minocycline poses a risk of tooth discoloration (Nakashima et al., 1989).

Therefore, when performing regenerative endodontic treatment in aesthetically critical areas, clinicians may consider using $Ca(OH)_2$ or eliminating minocycline from TAP, and sealing the coronal dentin using a bonding agent or composite resin.

Following the medicament placement, the access cavity is sealed with a sterile sponge followed by a provisional restoration (e.g., Cavit). The patient is recalled for follow-up in 3 to 4 weeks.

8.2 Second Appointment

At the second appointment, the patient should be assessed for resolution of any acute infection signs or symptoms (e.g., swelling, sinus tract, pain) that were present at the initial visit. If symptoms persist, antimicrobial treatment should be repeated.

Since apical bleeding will be induced during this visit, local anesthetics containing vasoconstrictors should be avoided. Instead, 3% mepivacaine is recommended, since it promotes bleeding into the root canal space.

Once proper isolation and coronal access are established, the canal should be carefully and thoroughly irrigated to remove the previous intracanal medicament. Ultrasonic activation should be performed with the tip positioned 2–3 mm short of the apical foramen.

When selecting an irrigation solution for this appointment, it is important to consider that NaOCl and chlorhexidine can exhibit direct or indirect cytotoxic effects on stem cells after dentin exposure. Therefore, continuing to use NaOCl at a reduced concentration (1.5%) is advisable.

Finally, 17% EDTA irrigation is beneficial, as it has been shown to promote the release of growth factors from dentin, and to support stem cell survival and differentiation.

Once the canal is dried with sterile paper points, a file is introduced slightly beyond the apical foramen to induce bleeding. Bleeding should ideally be allowed to rise up to the cementoenamel junction (CEJ) level, and a clot should be allowed to form (Sato et al., 1996).

Placement of a bioactive hydraulic cement such as Biodentine or MTA should be done in a 2–3 mm thickness, positioned as coronally as possible while leaving adequate space for a glass ionomer or composite restoration. Although MTA is widely used in case reports and has many desirable properties, it is known to cause significant coronal discoloration, making it less suitable in esthetically important areas.

As an alternative, Biodentine may be preferred, as encouraging studies have shown its ability to promote stem cell proliferation and odontoblastic differentiation.

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CHAPTER 2

DENTAL TRAUMATOLOGY

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1. INTRODUCTION TO DENTAL TRAUMATOLOGY

1.1. General Information

Traumatic dental injuries are defined as injuries to the dentition and surrounding tissues caused by internal or external forces that may impact patients' quality of life (Eranhikkal and Goswami 2020). Most dental traumas generally affect children between the ages of 7 and 12 and are often the result of falls or accidents near home or school (Andreasen and Ravn 1972; Skaare and Jacobsen 2003). About 25% of all school-aged children sustain a dental injury, and approximately 33% of adults—mostly before the age of 19—are exposed to traumatic injuries to their permanent teeth (Levin vd. 2020). Traumatic dental injuries rank as the fifth most prevalent condition worldwide. (Petti, Glendor, and Andersson 2018).

Children are more frequently exposed to dental trauma than adults due to their ongoing motor function development during growth periods (Glendor 2008). While home accidents are commonly observed in younger children, school-aged children are more frequently affected by falls, collisions, traffic accidents, and injuries related to sports and playing (Gassner vd. 2003).

In addition to negatively impacting occlusion, aesthetics, and function, dental trauma may also lead to psychological and social problems in some individuals. Therefore, protective measures should be taken against dental trauma; when it does occur, patients must be treated appropriately to minimize possible complications. Therefore, it is crucial to understand the etiology, distribution, and outcomes of trauma (Arhakis, Athanasiadou, and Vlachou 2017).

Traumatic dental injuries constitute a public oral health issue, and in the future, their prevalence may increase, as more individuals will be at risk. However, the rise in prevalence cannot be attributed solely to population growth (Glendor 2008). Other factors independent of population increase may contribute to this trend, such as:

A Greater Number of People at Risk: Increased use of cars, bicycles, and sports equipment, as well as lack of attention to safety measures, can raise the risk of injury.

Increase in the Elderly Population: In older individuals who retain their natural teeth, injuries due to falls and similar accidents may become more common.

Cultural and Social Changes: Environmental factors such as increased participation of women in sports or the popularity of new recreational activities may also influence the prevalence of dental trauma.

Therefore, population growth alone is not a determining factor; the rise in prevalence is more likely when combined with environmental and social factors, such as risky activities and lack of safety awareness. Predictions about increasing prevalence must consider broader environmental influences and individual behaviors (Glendor 2008).

2. EXAMINATION AND DIAGNOSIS

2.1. Medical History

In patient evaluation, the situation should first be assessed in terms of potential medical threats before considering dental conditions. In cases where the patient presents with loss of consciousness or excessive bleeding, immediate first aid must be initiated (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023).

A comprehensive medical history helps identify allergies, blood-related conditions, current medications, and other factors that could influence treatment decisions.

2.1.1. Medical Conditions Requiring Modification of Dental Treatment

CARDIOVASCULAR	PULMONARY	GI & RENAL	HEMATOLOGICAL, ENDOCRINE AND AUTOIMMUNE	NEUROLOGICAL
High and moderate risk of endocarditis	Chronic Obstructive Pulmonary Disease (COPD)	End-stage renal failure	Sexually transmitted diseases	Cerebrovascular trauma
Pathological heart murmur	Asthma	Hemodialysis	HIV and Acquired Immune Deficiency Syndrome (AIDS)	Seizure
Hypertension	Tuberculosis	Viral hepatitis (types B, C, D, and E)	Hypo and hyperthyroidism	Anxiety disorder
Unstable angina pectoris		Liver disease due to alcoholism	Diabetes	Depression

Recent myocardial infarction		Adrenal insufficiency	Rheumatoid arthritis	Bipolar disorder
Cardiac arrhythmia		Peptic ulcer	Systemic lupus erythematosus	Multiple sclerosis
Uncontrolled congestive heart failure		Inflammatory bowel disease	pregnancy	Parkinson's disease
		Pseudomembranous colitis	Bleeding disorders	History of substance and alcohol dependence
			Cancer	Alzheimer's disease
			Leukemia	Schizophrenia
			Osteoarthritis	Eating disorders
			Adrenal insufficiency	Neuralgia

If a patient has a medical condition requiring adjustments to dental care, it is imperative to obtain a consultation with the appropriate medical specialist. Such conditions may require adjustments in the treatment environment, scheduling, involvement of medical support staff, prophylactic measures, and selection of dental materials.

For instance, elective dental procedures should be postponed in patients exhibiting unstable angina or those who have experienced a myocardial infarction within the past 30 days. (James W. Little, Craig S. Miller, Nelson L. Rhodus 2018).

2.2. Dental History

To ensure the diagnosis is both prompt and correct and to determine the probable condition of the affected tissues, periodontium, and pulp, a systematic examination is essential in patients who have experienced trauma. In cases of acute trauma, the oral cavity is often heavily contaminated by the time the patient seeks treatment. So, the first step in examining the patient is to carefully clean the face and mouth. If soft tissue injuries are present, a gentle cleanser may be used. This cleaning stage also offers a chance to get an early sense of how serious the injury is (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007; Friend and Glenwright 1968).

Next, a series of questions should be asked to guide diagnosis and treatment planning. These questions include:

Trauma Assessment Questions and Explanations

Question	Purpose / Explanation
When did the injury occur?	The answer reveals the time factor. This is critical in the treatment of hard tissue (enamel, dentin, cementum), supporting tissue (periodontium), and surrounding tissues (lips, mandible, maxilla), as time has a direct impact on treatment options.
Where did the injury happen?	The answer may include legally important information and also indicate whether the wound may be contaminated.
How did the injury occur?	The answer points to the likely areas affected by the trauma. In children, if the injuries don't match the explanation given, it may indicate possible abuse, and input from other healthcare professionals should be sought. A notable delay in treatment also suggests possible child abuse.
Was there any loss of consciousness? If so, for how long?	Indicates signs of a concussion, which should require medical care and sometimes hospitalization. Patient should be immediately referred to ER if any signs of unconsciousness occur. After patient becomes medically stable urgent dental interventions can be made.
Were the teeth previously injured?	This can provide clarification for radiographic findings such as pulp canal obliteration or halted root development in a tooth that otherwise should have complete root formation.
Was any treatment done at the accident site or another clinic?	Teeth may have been replanted or kept in a medium after the accident. The patient might have been referred from a different emergency clinic, so it is important to know and document what was done there.
Is there any change in occlusion (bite)?	A positive answer can indicate tooth luxation, alveolar fracture, jaw fracture, or luxation/fracture of the temporomandibular joint.
Is there heightened sensitivity to hot and/or cold in the teeth?	A positive response suggests dentin exposure necessitating application of a protective liner or temporary restoration.

2.3. Extraoral and Intraoral Soft Tissue Examination

After trauma, extraoral tissues must be examined carefully. Before this assessment, any blood clots or hemorrhage present inside or around the mouth should be cleaned, and bleeding should be controlled with a sterile gauze before proceeding with the examination (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023 Ankara).

In the presence of a fracture of the alveolar process, multiple teeth might shift together as one unit, and gingival lacerations are commonly observed. Edema in the soft tissues may be an indicator of an underlying bone fracture. In cases where bone involvement is suspected or evident, surgical consultation is necessary (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023 Ankara).

During the extraoral examination, any scar tissue from previous injuries should be documented. Hemorrhage, swelling, or lacerations of the oral mucosa or gingival tissues should also be noted, and the need for sutures should be assessed (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023 Ankara).

Radiographic evaluation is mandatory immediately following any dentoalveolar injury. The selection of radiographs required for examining a trauma patient should be determined by the clinician based on the medical history and clinical findings, tailored to the individual case (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023 Ankara).

A decision should be made by weighing the risk of radiation exposure against the diagnostic value of the radiographs. ALARA should be kept at mind. When a foreign object is suspected within soft tissue, a brief exposure using an intraoral film placed between the suspected soft tissue area and the teeth is usually sufficient. Additionally, short-exposure lateral extraoral radiographs may be utilized if needed (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023 Ankara).

2.4. Clinical Examination

The examination should proceed from the outside inward. It begins with observation and palpation of the extraoral soft tissues and underlying bone. The characteristics of the wounds and the presence of any foreign bodies must be identified.

The intraoral soft tissues and alveolar bone should also be inspected and palpated. Next, an evaluation is made to check for hairline cracks or infractions in the hard tooth structures. Directing the examination light parallel to the labial surface of the injured tooth can greatly facilitate the detection of cracks.

In cases of crown fractures, the presence of pulp exposure (perforation) should be determined, and if present, the size of the exposure should be documented.

Additionally, any concomitant luxation injuries must be noted, as they can negatively impact pulpal healing and long-term prognosis (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007).

2.5. Radiographic Examination

Periapical radiographs should always be taken from multiple angulations to better assess the extent of trauma. Each case must be evaluated individually, and the clinician should determine which specific radiographs are necessary based on clinical findings.

There must be a clear justification for each radiograph taken—it should provide diagnostic information that will positively influence treatment decisions. Initial radiographs are also essential as they serve as a baseline for comparison in follow-up appointments.

The use of film holders is strongly recommended, as they facilitate standardization and reproducibility of radiographic imaging (Bourguignon vd. 2020).

Dental trauma most frequently affects the anterior region of the mouth, with the maxilla more commonly involved than the mandible (Bastone, Freer, and McNamara 2000). Because the maxillary central incisors are the most frequently affected teeth, the following radiographic images are recommended for a thorough assessment of the involved area:

1. A parallel periapical radiograph centered along the midline to visualize both maxillary central incisors.
2. A parallel periapical radiograph focusing on the maxillary right lateral incisor, which should also include the right canine and central incisor.
3. A parallel periapical radiograph focusing on the maxillary left lateral incisor, which should also include the left canine and central incisor.

4. A maxillary occlusal radiograph.
5. A minimum of one parallel periapical radiograph capturing the mandibular central incisors, including the lower anterior teeth.

In addition, if significant trauma is observed in the mandibular teeth, additional radiographs may be indicated (e.g., those listed above for maxillary teeth, along with a mandibular occlusal radiograph).

Radiographs of the maxillary lateral incisors offer alternative horizontal projections (mesial and distal) of each incisor and also include the canines. Occlusal radiographs offer a different vertical perspective of the affected teeth and surrounding tissues, which aids in the diagnosis of lateral luxations, root fractures, and alveolar bone fractures.

The above radiographic series is presented as an example. In case of involvement of other teeth, the series should be adjusted to focus on the specific injured tooth or teeth.

For simpler injuries—such as enamel fractures, uncomplicated crown fractures, or complicated crown fractures—not all of the above radiographs may be necessary.

Radiographs are essential for the precise identification of dental trauma. Root and bone fractures may occur without obvious clinical symptoms and can be overlooked if only one radiographic angle is used. In some instances, patients seek treatment weeks after the injury, once the visible signs of a significant injury have diminished. Therefore, dentists must use their clinical experience to weigh the advantages and disadvantages of obtaining multiple radiographic views.

Cone Beam Computed Tomography (CBCT) is a developed imaging method applied in the assessment of traumatic dental injuries, particularly in the visualization of root fractures, crown/root fractures, and lateral luxations. CBCT helps identify the location, width, and direction of a fracture. In such specific dental trauma cases, three-dimensional imaging can be beneficial and should be used when available.

When weighing the need for radiographic imaging, the guiding principle should be whether the resulting image will influence the course of treatment for the dental trauma (Bourguignon vd. 2020).

2.6. Mobility Test

The mobility test should assess the degree of looseness of a single tooth—particularly in the axial direction, which may indicate compromised pulpal blood circulation—as well as the mobility of a group of teeth, which may suggest an alveolar fracture. Mobility is assessed using a scale ranging from 0 to 3:

- 0 = None
- 1 = Mobility ≤ 1 mm in the horizontal direction
- 2 = Mobility ≥ 1 mm in the horizontal direction
- 3 = Axial (vertical) mobility

This classification helps in identifying the type of luxation.

It is crucial to distinguish between physiological mobility, ankylosis observed during follow-ups, and the absence of mobility seen in intrusion and lateral luxation cases during trauma.

Therefore, a mobility score of ‘0’ should be interpreted carefully. To differentiate between normal physiological mobility and a true absence of mobility, it should be evaluated in conjunction with percussion testing (J.O. Andreasen, F.M. Andreasen 1985).

2.7. Percussion Test

The percussion test, performed with a finger or the shaft of a metal instrument, serves two primary functions. Sensitivity to percussion indicates periodontal ligament (PDL) damage. Percussion from the labial surface can produce either a high or low-pitched sound.

A high-pitched, metallic tone suggests that the traumatized tooth **is** locked into the bone, as seen in lateral luxation or intrusion cases. During follow-up evaluations, this same tone is considered a sign of ankylosis.

This observation can be verified by placing a finger on the tooth’s lingual aspect. In a tooth with a healthy PDL, the impact of the percussion can typically be felt from the lingual side. In contrast, in cases of intrusion, lateral luxation, or ankylosis, the percussion effect is not easily perceived on the tested tooth (Reichborn-Kjennerud 1973).

2.8. Pulp Vitality Testing

Whenever possible, **electric pulp testing** should be performed, as it provides crucial information regarding the **neurovascular status** of the involved tooth. The most dependable response is produced when the electrode is placed on the **incisal edge**, or on the most intact enamel portion of the incisal edge in cases of crown fractures.

It is important to note that **immature teeth** (with incomplete root formation) may exhibit **higher threshold responses** or **inconsistent results** compared to teeth with fully developed roots. However, the outcome measured at the time of injury provides a reference point for future follow-up assessments.

Following traumatic injury, it is believed that the conductive capacity of nerve endings and/or sensory receptors is disrupted to a degree that may impair the neural transmission of electrical or thermal stimuli. As a result, a traumatized tooth may tend to give a false negative response to such pulp sensitivity tests (Pileggi, Dumsha, and Myslinksi 1996).

In teeth with complete root formation and closed apices, studies have shown that the return of normal blood flow to the coronal pulp can take as long as nine months post-injury. Once circulation is re-established, the tooth typically begins to respond again to pulp vitality testing (Gazelius, Olgart, and Edwall 1988).

If no response is recorded during follow-up sessions, irreversible pulp damage may be suspected—though even this is not definitive (Bhaskar and Rappaport 1973).

Lastly, due to poor patient cooperation, pulp sensitivity testing in primary dentition may not provide reliable diagnostic information (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007).

2.9. Photographic Records

In cases of dental trauma, it is important to **document injuries to the facial, intraoral soft and hard tissues through photographs** before any treatment is performed. These records are particularly valuable as **potential legal evidence** should the case proceed to litigation.

Additionally, photographic records contain valuable information for **monitoring prognosis and healing** after treatment. When obtaining **written informed consent** from patients, they should also be **informed about the use of photographic documentation**.

To protect patients' **legal rights**, clinicians must be familiar with and strictly adhere to the **relevant laws and regulations** of the country in which they are practicing (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023).

2.10. Evaluation in Terms of Tetanus Vaccination

Knowing the **environment in which the trauma occurred** is important for assessing the cleanliness of the wound site. *Clostridium tetani* is a **Gram-positive bacillus** that lives as a **commensal organism** in the intestines of humans and domestic animals and is also found in **cultivated soil.**

It is an **obligate anaerobe** that produces spores with a characteristic **"drumstick" appearance.** For germination (activation of spores), a **reduction in oxygen tension** is necessary (Babajews and Nicholls 1985). There is a risk of *C. tetani* transmission in **outdoor environments** (Eden E., Özer H., Kaval M.E., Çehreli Z. 2023)**.**

The **mortality rate of the disease** varies between **10% and 60%**, depending on factors such as individual health, treatment methods applied, and available healthcare services. The **optimal growth temperature** is between **33–37 °C**, and the **average incubation period** is approximately **7 days.**

Dentists can contribute to the diagnosis of tetanus, as **trismus** (lockjaw) is often the **first symptom** of the disease (Babajews and Nicholls 1985).

Republic of Turkey Ministry of Health – Childhood Vaccination Schedule, 2020

Vaccines	At Birth	End of 1st mo	End of 2nd mo	End of 4th mo	End of 6th mo	End of 9th mo	End of 12th mo	End of 18th mo	End of 24th mo	End of 30th mo	End of 36th mo	End of 48th mo	13 years
Hepatitis B	I	II			III								
BCG (Tuberculosis)			I										
DaBT-IPA-Hib			I	II	III			R					
KPA*			I	II			R						
MMR						ID**	I					II	
DaBT-IPA												R	
OPA					I			II					
Td													R
Hepatitis A								I	II				
Varicella							I						

* As of 01.01.2019, infants born after this date will receive vaccines at the 2nd, 4th, and 12th months.

** As per BDK (Immunization Advisory Committee) decision dated 25.09.2019, in outbreak-risk areas, an additional dose of a measles-containing vaccine (K or MMR) will be administered in the 9th–11th month.

*** Starting from children born on or after July 11, 2016, all children who have reached the 48th month will be vaccinated. For children born before July 1, 2016, and who have not yet started primary school, the second dose of MMR and the DaBT-IPA vaccine will be administered during the 2020–

2021, 2021–2022, and 2022–2023 academic years in 1st grade of primary school.

Legend:

DaBT-IPA-Hib: Diphtheria, Acellular Pertussis, Tetanus, Inactivated Polio, Haemophilus Influenza Type b (Pentavalent Vaccine)

KPA: Conjugated Pneumococcal Vaccine

MMR: Measles, Mumps, Rubella

DaBT-IPA: Diphtheria, Acellular Pertussis, Tetanus, Inactivated Polio (Quadrivalent Vaccine)

OPA: Oral Polio Vaccine (Childhood Polio Vaccine)

Td: Adult Type Diphtheria-Tetanus Vaccine

A single dose of tetanus vaccine does not provide long-term protection. A second dose provides protection in approximately 90% of individuals within 2–4 weeks; however, this increase is short-lived. A third dose, if administered at least 5 years later, provides nearly lifelong protection (Babajews and Nicholls 1985).

Tetanus toxoid vaccine is available in the following forms: monovalent tetanus toxoid, combined with diphtheria, or as a trivalent formulation with diphtheria and pertussis (DTaP vaccine)(Yen, Thwaites 2019).

According to the World Health Organization's Expanded Program on Immunization (EPI)**,** it is recommended to administer three doses of the trivalent DTP vaccine at 2, 3, and 4 months of age (DTP3), followed by booster doses at ages 4–7 and again at 15 years (Gayatri Amirthalingam v.d. GOV.UK 2023).

In the United Kingdom, five doses are recommended for long-term protection.

Differences in national immunization schedules should be considered when evaluating vaccination protocols.

2.10. Legal Documentation

In cases of dental trauma, maintaining forensic records and photographing the case is of critical importance. In emergency departments where law enforcement personnel are not present, the responsible police department, gendarmerie station, or the Office of the Public Prosecutor must be informed of the forensic incident. Prepared forensic reports should be delivered in person with a signed receipt, and any verbal reports made by phone should also be documented.

To determine the nature of the crime and identify the offender, remedy the victim's harm, while ensuring the provider acts in the patient's best interest, it is vital to preserve evidence until the arrival of responsible parties such as the forensic physician, law enforcement, or the prosecutor.

Any situation in which a person's physical or mental health is compromised due to the intentional act, negligence, recklessness, or carelessness of another individual should be considered a forensic case(Eden E., Özer H., Kaval M.E., Çehreli Z. 2023).

Examples of forensic cases under this definition include:

- All injuries caused by another person's intentional, negligent, or reckless behavior
- (e.g., a person slipping and falling due to a floor mopped without wringing the mop, or a patient falling off a stretcher due to the guardrail not being raised);
- Assault by another person (including family members);
- Injuries from sharp, sharp-penetrating, or blunt instruments; injuries from explosive devices or firearms (e.g., Molotov cocktails, etc.);
- Traffic accidents; falls; occupational injuries; poisonings (including food-related); suspected intoxications (including drug overdoses);
- Use of illegal substances (e.g., ecstasy, etc.);
- Self-harm (suicide attempts);
- Electrocution, lightning strikes, and burns;
- Insertion of foreign objects into the body by any means (e.g., bottles, glasses);
- Any form of suspicious death;
- Human rights violations;
- Allegations of torture;
- Cases of sexual assault;
- Injuries occurring in custody or prison;
- Animal bites, scratches, stings (e.g., from cats, dogs, bees);
- Cases of mechanical asphyxia (e.g., drowning, hanging);

- Neglect or abuse by immediate or extended family members.

2.11. Domestic Violence and Abuse

According to The World Health Organization (WHO), violence is defined as "the use of force that carries the potential to cause harm to oneself, another person, a group, or society." (World Health Organization 2013). Despite being a public health issue that affects individuals, families, and legal systems, abuse is ultimately shaped by individual attitudes and behaviors and directly impacts the physical, developmental, and psychosocial well-being of others (Till-Tentschert 2017).

It has been reported that 36.7% of injuries related to domestic violence and abuse (DVA) happen in the head and neck region. In DVA cases, the most frequently observed injuries are fractures of the teeth and/or jawbones, with the incisors being the most commonly affected teeth (Garbin vd. 2012).

Additional findings in such cases may include:

- Ecchymosis (bruising),
- Swelling,
- Lacerations,
- Tears in the oral mucosa,
- Temporomandibular joint disorders,
- Tooth mobility or displacement,
- Difficulty in chewing and speaking,
- Restricted mouth opening, and
- Tooth loss(Caldas vd. 2012).

In DVA cases, dentists are not only responsible for examining the victim, but also legally obligated to report the incident to the appropriate authorities(Mascarenhas, Deshmukh, and Scott 2009).

Because of their focus on the orofacial region, dentists play a crucial role in the detection of female victims of domestic violence and abuse(Da Nóbrega vd. 2017; Tjaden and Thoennes t.y.)circumstances of aggressions, and patterns of trauma. Descriptive and multivariate statistics using decision tree analysis by the Chi-squared automatic interaction detector (\n CHAID\n . Numerous studies have shown that training in this area increases dentists' awareness and positively influences their attitudes toward recognizing and responding to DVA(Danley vd. 2004; Hsieh vd. 2006).

In cases of dental trauma where child abuse is suspected, it is essential that the dentist report the case to the relevant authorities without delay.

3. CLASSIFICATIONS

3.1. Andreasen Dental-Alveolar Trauma Classification (1981)

Code	Injury	Criteria
(a) Injuries to the hard dental tissues and the pulp (Fig. 8.1).		
Code	**Injury**	**Criteria**
N 502.50	Enamel infraction	An incomplete fracture (crack) of the enamel without loss of tooth substance (Fig. 8.1, A).
N 502.50	Enamel fracture (uncomplicated crown fracture)	A fracture with loss of tooth substance confined to the enamel (N 502.50) (Fig. 8.1, A).
N 502.51	Enamel-dentin fracture (uncomplicated crown fracture)	A fracture with loss of tooth substance confined to enamel and dentin, but not involving the pulp (Fig. 8.1, B).
N 502.52	Complicated crown fracture	A fracture involving enamel and dentin, and exposing the pulp (Fig. 8.1, C).
N 502.54	Uncomplicated crown-root fracture	A fracture involving enamel, dentin and cementum, but not exposing the pulp (Fig. 8.1, D).
N 502.54	Complicated crown-root fracture	A fracture involving enamel, dentin and cementum, and exposing the pulp (Fig. 8.1, E).
N 502.53	Root fracture	A fracture involving dentin, cementum, and the pulp (Fig. 8.1, F). Root fractures can be further classified according to displacement of the coronal fragment, see under Luxation injuries.
(b) Injuries to the periodontal tissues (Fig. 8.2).		
Code	**Injury**	**Criteria**
N 503.20	Concussion	An injury to the tooth-supporting structures without abnormal loosening or displacement of the tooth, but with marked reaction to percussion (Fig. 8.2, A).
N 503.20	Subluxation (loosening)	An injury to the tooth-supporting structures with abnormal loosening, but without displacement of the tooth (Fig. 8.2, B).
N 503.20	Extrusive luxation (peripheral dislocation, partial avulsion)	Partial displacement of the tooth out of its socket (Fig. 8.2, C).
N 503.20	Lateral luxation	Displacement of the tooth in a direction other than axially. This is accompanied by comminution or fracture of the alveolar socket (Fig. 8.2, D).
N 503.21	Intrusive luxation (central dislocation)	Displacement of the tooth into the alveolar bone. This injury is accompanied by comminution or fracture of the alveolar socket (Fig. 8.2, E).
N 503.22	Avulsion (exarticulation)	Complete displacement of the tooth out of its socket (Fig. 8.2, F).
(c) Injuries to the supporting bone (Fig. 8.3).		
Code	**Injury**	**Criteria**
N 502.40	Comminution of the maxillary alveolar socket	Crushing and compression of the alveolar socket. This condition is found concomitantly with intrusive and lateral luxations (Fig. 8.3, A).
N 502.60	Comminution of the mandibular alveolar socket	
N 502.40	Fracture of the maxillary alveolar socket wall	A fracture confined to the facial or oral socket wall (Fig. 8.3, B).
N 502.60	Fracture of the mandibular alveolar socket wall	
N 502.40	Fracture of the maxillary alveolar process	A fracture of the alveolar process which may or may not involve the alveolar socket (Figs 8.3, C and D).
N 502.60	Fracture of the mandibular alveolar process	
N 502.42	Fracture of the maxilla	A fracture involving the base of the maxilla or mandible and often the alveolar process (jaw fracture). The fracture may or may not involve the alveolar socket (Figs 8.3, E and F).
N 502.61	Fracture of the mandible	
(d) Injuries to gingiva or oral mucosa (Fig. 8.4).		
Code	**Injury**	**Criteria**
S 01.50	Laceration of gingiva or oral mucosa	A shallow or deep wound in the mucosa resulting from a tear, and usually produced by a sharp object (Fig. 8.4, A).
S 00.50	Contusion of gingiva or oral mucosa	A bruise usually produced by impact with a blunt object and not accompanied by a break in the mucosa, usually causing submucosal hemorrhage (Fig. 8.4, B).
S 00.50	Abrasion of gingiva or oral mucosal	A superficial wound produced by rubbing or scraping of the mucosa leaving a raw, bleeding surface (Fig. 8.4, C).

3.2. International Classification of Diseases

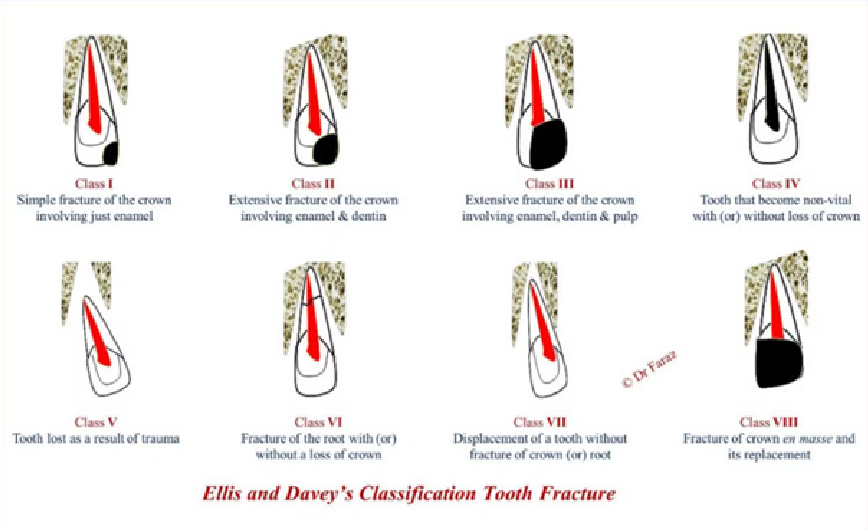
The version implemented by the World Health Organization (WHO) follows Proposal No. 2130, which was submitted to the ICD-11 Maintenance Platform in 2018, and finalized at the end of the 2022 review process.

	Proposal #2130	Implemented version	ICD-11 Code
Block name	Traumatic Dental Injuries	Injury of teeth or supporting structures	NA0D
First group	Injuries to the hard dental tissues and the pulp	Injury of hard dental tissues and pulp	NA0D.0
	Enamel infraction[a]	Enamel infraction	NA0D.00
	Enamel fracture	Enamel fracture	NA0D.01
	Enamel-dentin fracture	Enamel-dentin fracture	NA0D.02
	Complicated crown fracture	Complicated crown fracture	NA0D.03
	Uncomplicated crown-root fracture	Uncomplicated crown-root fracture	NA0D.04
	Complicated crown-root fracture	Complicated crown-root fracture	NA0D.05
	Root fracture	Root fracture	NA0D.06
		Other specified injury of hard dental tissues and pulp	NA0D.0Y
		Injury of hard dental tissues and pulp, unspecified	NA0D.0Z
Second group	Injuries to the periodontal tissues	Injury of periodontal tissues	NA0D.1
	Concussion[a]	Concussion of periodontal tissue	NA0D.10
	Subluxation[a]	Subluxation of tooth	NA0D.11
	Extrusive luxation	Extrusive luxation of tooth	NA0D.12
	Lateral luxation	Lateral luxation of tooth	NA0D.13
	Intrusive luxation	Intrusive luxation of tooth	NA0D.14
	Avulsion	Avulsion of tooth	NA0D.15
		Other specified injury of periodontal tissues	NA0D.1Y
		Injury of periodontal tissues, unspecified	NA0D.1Z
Other groups		Other specified injury of teeth or supporting structures	NA0D.Y
		Injury of teeth or supporting structures, unspecified	NA0D.Z

[a]Entities that were not classifiable using the ICD system before the revision.

3.3. Ellis and Davey Classification (1970)

In 1970, Ellis and Davey suggested a tooth fracture classification based on the severity of structural damage. This system has been widely accepted and has been used by dentists to evaluate the severity of dental trauma and to develop appropriate treatment plans accordingly(Ellis and Davey 1970).



3.4. Eden Baysal Dental Trauma Index (2021)

The EBDTI is a five-step index designed to record information about injured tissues, including apical development status and the presence of bone injury, which are critical for treatment planning. In this index, injuries to the dental tissues (enamel, cementum, dentin, pulp), periodontal tissues, and alveolar bone are recorded separately, and the status of apical maturation is also documented.

The definitions of traumatic injuries are derived from the definitions provided in the Andreasen classification.

The EBDTI consists of five components, following the FDI tooth number (written in parentheses), and can be used for both dentitions. The format of the five-part code is as follows:

- The first two components are expressed in numerals,
- The third component is written in uppercase letters,
- The fourth component is written in lowercase letters,
- The fifth component is indicated by a plus (+) or minus (–) sign.

The tooth number of the traumatized tooth is written in parentheses, using the FDI notation system, which is as follows:

FDI Tooth Numbering for Permanent Dentition:

18 · 17 · 16 · 15 · 14 · 13 · 12 · 11	21 · 22 · 23 · 24 · 25 · 26 · 27 · 28
48 · 47 · 46 · 45 · 44 · 43 · 42 · 41	31 · 32 · 33 · 34 · 35 · 36 · 37 · 38

FDI Tooth Numbering for Primary (Deciduous) Dentition:

55 · 54 · 53 · 52 · 51	61 · 62 · 63 · 64 · 65
85 · 84 · 83 · 82 · 81	71 · 72 · 73 · 74 · 75

First Step

The first step, following the FDI code, classifies crown-related trauma observed during clinical examination.

This classification progresses from minor to severe injuries, scored from 0 to 5 as follows:

- 0 = None
- 1 = Enamel fracture/crack
- 2 = Enamel-dentin fracture without pulp exposure
- 3 = Enamel-dentin fracture with pulp exposure
- 4 = Uncomplicated crown-root fracture (involving enamel, dentin, and cementum, but not the pulp)
- 5 = Complicated crown-root fracture (involving enamel, dentin, cementum, and pulp)

Second Step

The second step identifies the location of a root fracture based on the root's anatomical thirds**.**

If there is multiple root fractures, the one with the poorest prognosis—typically the most cervical one—should be recorded.

- 0 = None
- 1 = Fracture in the apical third
- 2 = Fracture in the middle third
- 3 = Fracture in the cervical third

Third Step

The third step denotes injuries to the periodontal tissues.

These are coded using the first letter (uppercase) of the English name of the type of luxation injury.

Since all luxation injury types begin with different letters, this avoids confusion.

If desired, researchers may also adapt this system using the initials of injury names in their own language, based on established dental terminology.

For example, instead of using “N = None”, one may use “Y = Yok” in Turkish, or “C = Concussion” may be replaced with “K = Konküzyon”.

In languages where several terms may start with the same letter, using the English version of the index is advised to prevent confusion.

Below is the coding for luxation injuries in both English and Turkish:

Code	English Term	Turkish Equivalent
N	None	Y = Yok
A	Avulsion	A = Avülsiyon
C	Concussion	K = Konküzyon
S	Subluxation	S = Sublüksasyon
E	Extrusive Luxation	E = Ekstrüziv Lüksasyon
L	Lateral Luxation	L = Lateral Lüksasyon
I	Intrusive Luxation	İ = İntrüziv Lüksasyon

Fourth Step

The fourth step indicates the maturation status of the apex.

A permanent tooth is considered mature when its apex is fully formed and standard root canal treatment can be carried out without complication.

If the dentist is uncertain, it should be recorded as immature.

For primary teeth, the status of root development is determined by radiographic findings and the child’s age.

The ‘r’ code is used exclusively to record root resorption in primary teeth.

In this index, the status of the apex is indicated by using the lowercase initial of the relevant term.

Code	Description
m	mature apex
i	immature apex
r	resorbing apex

Fifth Step

The fifth step indicates whether a fracture in the jawbone is present.

This refers specifically to a fracture of the jawbone due to a forceful impact to the facial region.

Fractures of the vestibular bone that can arise due to lateral luxation, or compression of the bone during intrusion, are not recorded in this step, as they do not represent additional fractures and do not affect the treatment approach.

The presence of a jaw fracture is coded with a plus sign (+), and its absence with a minus sign (–).

Code	Description
+	Fracture present
–	No fracture detected

3.4.1. Modified Eden Baysal Dental Trauma Index

The Modified EBDTI allows for the recording of soft tissue trauma (such as those affecting facial skin, lips, gingiva, tongue, etc.) that occur in addition to dental trauma.

After recording the dental injuries using the standard EBDTI, the code is enclosed in square brackets, and the soft tissue injuries are indicated as superscript values placed outside the brackets.

Soft tissue injuries are coded from 0 to 8, starting from extraoral areas.

For extraoral injuries, skin and lip injuries are assessed, while for intraoral injuries, gingiva, tongue, and frenulum injuries are recorded.

If a patient presents with multiple soft tissue injuries, these are listed in sequence, separated by commas (Eden and Yılmaz 2021).

Table 1: Summary of codes used in 'Eden Baysal Dental Trauma Index' (Illustrated by Alara Ayraç)

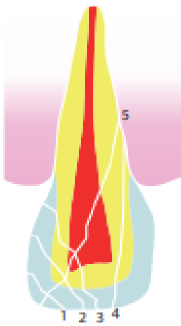
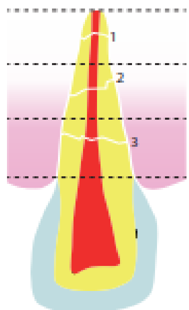
Number of tooth (FDI)	1st digit Crown Fracture	2nd digit Root Fracture	3rd digit Luxation Injury	4th digit Maturity of Apex	5th digit Alveolar process injury
	0 =none	0 =none	CAPITAL FIRST LETTERS	small first letters	+ or -
			N= None C= Concussion S= Subluxation E= Extrusive Luxation L= Lateral Luxation I= Intrusive Luxation A= Avulsion	i = immature apex m = mature apex r= resorbed apex	(+ sign) alveolar process injury (- sign) No alveolar process injury

Table 2: Soft Tissue Injury Codes Used in the Modified Eden Baysal Dental Trauma Index

Modified EBDTI Codes	Description
[(..)….]^0	0 = None
[(..)….]^1	1 = Skin/Lip abrasion – soft tissue scraped
[(..)….]^2	2 = Skin/Lip laceration – tissue cut/torn
[(..)….]^3	3 = Skin/Lip contusion – soft tissue bruising
[(..)….]^4	4 = Skin/Lip avulsion – tissue torn away
[(..)….]^5	5 = Intraoral abrasion – mucosa scraped
[(..)….]^6	6 = Intraoral laceration – mucosa cut/torn
[(..)….]^7	7 = Intraoral contusion – mucosal bruising
[(..)….]^8	8 = Intraoral avulsion – mucosal detachment

The following image shows a trauma case affecting the primary dentition in a 2.5-year-old male child.

Upon extraoral examination, no soft tissue injuries were observed on the patient's face or lips. Intraoral examination revealed lateral luxation of teeth 51 and 61 (maxillary right and left primary central incisors), characterized by gingival bleeding and premature contact with the mandibular incisors. No damage was noted on the crowns of the teeth during intraoral inspection. However, abrasion was detected on the gingival tissue in the region of tooth 52 (maxillary right primary lateral incisor). Periapical radiograph showed no root fractures. According to the radiographic assessment, the roots of teeth 51 and 61 (maxillary right and left primary central incisors) are fully developed. Clinical and radiographic findings indicate that there is no associated alveolar bone fracture. The Modified Eden Baysal Dental Trauma Index (EBDTI) code for this patient is: [(51) 0 0 L m –, (61) 0 0 L m –]5

3.2. International Classification of Diseases

The version implemented by the World Health Organization following the review process in 2022 and the proposal number 2130 submitted to the Maintenance Platform of the 11th Revision of the ICD (ICD-11) in 2018 (Petti et al., 2022).

TABLE 1 Traumatic dental injury classifications. Proposal #2130 submitted to the Maintenance Platform of the International Classification of Diseases 11th Revision (ICD-11) in 2018, and version implemented by the World Health Organization at the end of the reviewing process in 2022

	Proposal #2130	Implemented version	ICD-11 Code
Block name	Traumatic Dental Injuries	Injury of teeth or supporting structures	NA0D
First group	Injuries to the hard dental tissues and the pulp	Injury of hard dental tissues and pulp	NA0D.0
	Enamel infraction[a]	Enamel infraction	NA0D.00
	Enamel fracture	Enamel fracture	NA0D.01
	Enamel-dentin fracture	Enamel-dentin fracture	NA0D.02
	Complicated crown fracture	Complicated crown fracture	NA0D.03
	Uncomplicated crown-root fracture	Uncomplicated crown-root fracture	NA0D.04
	Complicated crown-root fracture	Complicated crown-root fracture	NA0D.05
	Root fracture	Root fracture	NA0D.06
		Other specified injury of hard dental tissues and pulp	NA0D.0Y
		Injury of hard dental tissues and pulp, unspecified	NA0D.0Z
Second group	Injuries to the periodontal tissues	Injury of periodontal tissues	NA0D.1
	Concussion[a]	Concussion of periodontal tissue	NA0D.10
	Subluxation[a]	Subluxation of tooth	NA0D.11
	Extrusive luxation	Extrusive luxation of tooth	NA0D.12
	Lateral luxation	Lateral luxation of tooth	NA0D.13
	Intrusive luxation	Intrusive luxation of tooth	NA0D.14
	Avulsion	Avulsion of tooth	NA0D.15
		Other specified injury of periodontal tissues	NA0D.1Y
		Injury of periodontal tissues, unspecified	NA0D.1Z
Other groups		Other specified injury of teeth or supporting structures	NA0D.Y
		Injury of teeth or supporting structures, unspecified	NA0D.Z

[a]Entities that were not classifiable using the ICD system before the revision.

4. TREATMENT GUIDELINES

4.1. Hard Tissue Injuries

4.1.1. Enamel Infraction and Fracture

A hairline crack in the enamel without any actual loss of tooth substance is known as an enamel infraction. Crown fractures most commonly occur in young, caries-free anterior teeth (Järvinen, 1979; Love & Ponnambalam, 2008). No sensitivity is present upon percussion and palpation. If sensitivity is detected, the tooth should be assessed for signs of potential luxation or a root fracture. Mobility is within normal limits. The pulp sensitivity test generally yields a positive response. No radiographic anomalies are observed. The recommended radiographs include:

A parallel periapical radiograph is recommended, and if signs or symptoms of other possible injuries are present, additional radiographs are indicated.

In cases with visible cracks, application of resin following acid etching is advised to prevent discoloration and bacterial infiltration of the cracks. No additional intervention is required.

If it is verified that the damage is confined solely to an enamel infraction, follow-up is not necessary. However, if there is an accompanying injury such as luxation, the follow-up protocol specific to that injury should be followed (Bourguignon et al., 2020).

4.1.2. Uncomplicated Crown Fracture

This type of crown fracture is limited to th enamel and dentin without pulpal exposure.

Mobility is within normal limits. The pulp sensitivity test generally yields a positive response. No sesitivity upon percussion and palpation is detected. If sensitivity is observed, the tooth should be evaluated for a possible luxation injury or root fracture.

Visible loss of enamel-dentin structure is present. If the fractured piece is missing and soft tissue injuries have occured, radiographs of the lips and/or cheeks are indicated to search for the missing tooth fragment or foreign bodies.

A parallel periapical radiograph is among the recommended scans, and if any indications or symptoms of other potential injuries are present, additional radiographs are indicated.

If the fractured fragment is available and undamaged, it may be reattached to the tooth. If the fragment is dry, it should be rehydrated by immersing it in water or saline for 20 minutes prior to reattachment.

Exposed dentin may be capped with glass ionomer cement or restored with a bonding agent and composite resin.

When the exposed dentin lies less than 0.5 mm from the pulp—appearing pink but not actively bleeding—it should be covered with calcium hydroxide and sealed using a material like glass ionomer.

Temporary restorations should be replaced using an appropriate permanent restorative material at the earliest opportunity (Bourguignon et al., 2020).

4.1.3. Complicated Crown Fracture

This category of fractures involves enamel, dentin, and pulp.

Mobility is within normal limits. No sensitivity is detected upon palpation and percussion. If sensitivity is detected, the tooth should be carefully assessed for a possible luxation injury or root fracture.

The exposed pulp is reactive to triggers such as air, cold, or sweet substances. A visible loss of enamel and dentin is present.

If the fractured fragment is missing and soft tissue injuries are observed, radiographs of the lips and/or cheeks are indicated to detect the missing tooth fragment or foreign bodies.

Recommended radiographs include a parallel periapical radiograph, additional radiographs should be considered if there are clinical signs or symptoms pointing to other possible injuries. In teeth with incomplete root development and open apices, pulp preservation is of utmost importance. Partial pulpotomy or pulp capping is recommended to promote continued root development.

Vital pulp therapies (e.g., partial pulpotomy) are also preferred in teeth with complete root development.

Non-setting calcium hydroxide or silicate cements that do not stain the tooth are suitable materials for covering the exposed pulp.

In mature teeth where post placement is required for crown retention, root canal treatment is the preferred option.

If the broken fragment is available, it can be reattached to the tooth following rehydration and suitable pulp therapy.

Without the presence of the fractured piece, exposed dentin should be covered with glass ionomer or restored using a bonding agent and composite resin.

Temporary restorations should be replaced with an appropriate permanent restorative material as soon as possible (Bourguignon et al., 2020).

4.1.3.1. Cvek Pulpotomy

Pulpotomy involves removing a portion of the dental pulp while preserving the vitality of the remaining tissue, enabling it to continue functioning normally (Bimstein & Rotstein, 2016).

The scope of a pulpotomy is influenced by various factors, such as whether the tooth is primary or permanent, the cause of pulp exposure (carious or traumatic), the stage of root development (open or closed apex), the complexity of the crown fracture (complicated or uncomplicated), the presence of periodontal or alveolar bone injuries, and the condition of the pulp at the time of treatment. The majority of pulpotomies in primary teeth are done following carious pulp exposure and involve complete extraction of the coronal pulp (Dean, 2016). In contrast, pulp exposures due to complicated crown fractures in permanent teeth are most commonly treated with Cvek pulpotomy, which involves the removal of 1–3 mm of coronal pulp close to the exposure site (Bimstein & Rotstein, 2016).

With few clinical exceptions, cervical pulpotomy is no longer the treatment of choice for complicated crown fractures in permanent teeth, as Cvek pulpotomy offers a better prognosis. Unlike cervical pulpotomy, the Cvek technique retains the coronal pulp tissue, which is rich in cells and has a higher capacity for healing compared to the more fibrous, single-cell-type radicular pulp.

Clinical and histological findings validate the use of Cvek as a definitive treatment for both immature and mature permanent teeth with complicated crown fractures. Reported success rates for Cvek pulpotomies in permanent teeth with complicated crown fractures vary within the range of 87.5% to 100% (Bimstein & Rotstein, 2016).

Although one clinical study indicated that Cvek pulpotomy has shown success in cases where pulp exposure spans from 0.5 to 4.0 mm, its outcome in teeth with exposures greater than 4 mm has not yet been clearly established (Cvek, 1978).

Nevertheless, the benefits of Cvek pulpotomy surpass the potential drawbacks of cervical pulpotomy or pulpectomy, which may include crown discoloration, weakened tooth structure, and the need for apexification or apexogenesis in developing teeth. Pulp and periodontal healing in traumatized teeth is strongly influenced by factors such as the injury's severity, any additional trauma sustained during the same event, the extent of pulp exposure, the time delay before treatment, and the stage of root development (Bimstein & Rotstein, 2016).

When calcium hydroxide ($Ca(OH)_2$) is used, the prognosis of partial pulpotomy depends less on the exact form of $Ca(OH)_2$ and more on its application and the effectiveness of the seal within the root canal, which is crucial for protecting the remaining pulp from microbial contamination.

The same protocols apply to the use of mineral trioxide aggregate (MTA). When performing partial pulpotomy on permanent teeth affected by carious pulp involvement, there is no statistically significant difference in success rates between teeth treated with calcium hydroxide (91%) and those treated with MTA (93%) (Bimstein & Rotstein, 2016).

The degree of pulp inflammation is a critical factor for pulpotomy success. Therefore, the clinician should make a treatment decision for complicated crown fractures based on the following considerations:

- Ability to initiate treatment as soon as possible, reducing the likelihood of pain, pulp necrosis, and infection. Current literature suggests that a delay of up to 9 days between trauma and treatment may have minimal impact on the result of Cvek pulpotomies.

- Exposure size has no significant effect on the outcome, provided it is less than 4 mm.
- Cvek pulpotomy has a better prognosis in teeth with open apices than in those with closed apices—especially important in cases where a concomitant luxation injury is present (Bimstein & Rotstein, 2016).

4.1.4. Uncomplicated Crown-Root Fracture

This type of fracture includes enamel, dentin, and cementum (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007).

The pulp sensitivity test is generally positive, and the presence of sensitivity upon percussion is usually present. A fragment from the coronal, mesial, or distal aspect is typically present and mobile. It is important to evaluate whether the fracture line extends above or below the gingival margin. Apical extension of the fracture may not be clinically detectable.

If the fractured fragment is missing and soft tissue injuries are present, radiographs of the lips and/or cheeks should be taken to locate the lost fragment or detect any foreign bodies.

Recommended radiographic examinations include:

- A standard parallel periapical X-ray
- Two supplementary radiographs captured from different vertical and/or horizontal angles
- An occlusal radiograph

Cone-beam computed tomography (CBCT) can be used to obtain a clearer view of the fracture line, including its width and proximity to the marginal bone. CBCT is also helpful in evaluating the crown-to-root ratio and planning appropriate treatment options.

Until a definitive treatment plan is established, the mobile fragment can be temporarily bonded to adjacent teeth or to the immobile portion of the same tooth.

If there is no pulp exposure, the coronal or mobile fragment can be carefully removed, and the tooth can be restored. Any exposed dentin should be protected with glass ionomer cement or restored using a bonding agent combined with composite resin (Bourguignon et al., 2020).

Long-Term Treatment Options

Planning the treatment will partially depend on the patient's age and cooperation level. Potential long-term treatments may include:

- Extrusion of the apical or immobile portion through orthodontic means, followed by restoration (periodontal recontouring surgery may be necessary afterward)
- Surgical extrusion
- Root canal treatment should be carried out if the pulp becomes necrotic or infected, followed by appropriate restoration
- Planned replantation, optionally involving rotation of the tooth
- Tooth extraction
- Autotransplantation (Bourguignon et al., 2020)

4.1.5. Complicated Crown-Root Fracture

This type of fracture involves enamel, dentin, cementum, and the pulp.

The pulp sensitivity test is generally positive. The tooth is responsive to percussion. A coronal, mesial, or distal fragment is typically present and mobile. The extension of the fracture line (subgingival or supragingival) must be assessed. Clinical visibility of the apical extension of the fracture may be in question. If the fractured fragment is missing and soft tissue injuries are present, radiographic imaging of the lips and/or cheeks is recommended to identify any missing tooth fragments or foreign objects.

Recommended imaging consists of a parallel periapical radiograph, two additional views from varying vertical and/or horizontal angles, and an occlusal radiograph. To more clearly visualize the fracture's trajectory, width, and its proximity to the marginal bone, CBCT may be utilized. It is also valuable for assessing the crown-to-root ratio and assisting in treatment planning.

Until a definitive treatment plan is established, the mobile fragment may be temporarily bonded to adjacent teeth or to the immobile part of the same tooth.

In immature teeth with incomplete root development, preserving pulp vitality through partial pulpotomy is important. Rubber dam isolation may be difficult but ought to be attempted. Non-setting calcium hydroxide or silicate cements that do not stain the tooth are appropriate materials for covering the exposed pulp.

For mature teeth with full root development, removing the pulp is generally recommended.

Exposed dentin may be covered with glass ionomer or restored using a bonding agent and composite resin (Bourguignon et al., 2020).

Long-Term Treatment Options

The level of cooperation and the patient's age partially determine the treatment plan. Potential treatments include:

- Completion of root canal therapy followed by placement of a coronal restoration
- Orthodontic extrusion of the apical segment (periodontal recontouring surgery may be necessary afterward)
- Surgical extrusion
- Intentional retention of the root
- Planned replantation, with or without rotating the tooth
- Tooth extraction
- Autotransplantation (Bourguignon et al., 2020)

4.1.6. Root Fracture

- Root fractures involve the dentin, pulp, and cementum, and the fracture line may present as horizontal, oblique, or a combination of both. The coronal portion of the tooth may be mobile or displaced. Percussion sensitivity is frequently noted, and bleeding from the gingival sulcus is often observed.
- The pulp sensitivity test may initially yield a negative result, indicating transient or permanent neurovascular damage. Root fractures may occur at any level. Recommended imaging includes a parallel periapical radiograph, two additional views taken from varying vertical and/or horizontal angles, and an occlusal radiograph.

Root fractures are frequently missed without additional imaging. If standard radiographs fail to offer adequate detail for treatment planning, CBCT is advised to accurately determine the fracture's location, severity, and direction.

If the coronal fragment is displaced, it should be promptly repositioned and confirmed radiographically. The segment should then be stabilized using a passive, flexible splint for a duration of four weeks.

If the fracture is in the cervical area, longer stabilization—up to 4 months—may be indicated.

Cervical root fractures are capable of healing. Therefore, if the coronal fragment is stable, it should be left in place during emergency care.

During emergency intervention, endodontic treatment should not be intitated. Healing of the fracture should be monitored for no less than a year, along with the pulpal health.

Pulp infection and necrosis may develop during follow-up and usually occur only in the coronal section. Therefore, endodontic treatment is indicated for the coronal pulp only.

Due to the frequently oblique nature of root fractures, determining the working length can be dfficult, and an apexification may be necessary.

The apical fragment rarely exhibits pathological changes significant enough to warrant treatment.

- In mature teeth where the cervical fracture lies above the alveolar crest and the coronal fragment is highly mobile, extraction of the fragment is required, followed by root canal treatment and restoration with a post-retained crown.
- As in crown-root fractures, additional long-term treatment options may include:
- Apical segment extrusion through orthodontic means
- Crown lengthening surgery
- Surgical extrusion
- Tooth extraction
- (Bourguignon et al., 2020)

4.1.7. Alveolar Fracture

This type of fracture includes the alveolar bone and may involve adjacent bone structures. A complete alveolar fracture involves the bone extending from the buccal to the palatal aspect in the maxilla, or from the buccal to the lingual side in the mandible. A characteristic finding is a displaced and mobile bone segment involving multiple teeth that move together as a unit. Displacement and misalignment of the fractured alveolar segment often lead to occlusal disturbances.

Dentition within the fractured segment may show no response to pulp sensitivity tests. Fracture lines may occur at any point between the marginal bone and the root apex. Suggested radiographic evaluation includes a parallel periapical image, two supplementary views from different vertical and/or horizontal angles, and an occlusal radiograph. If these images do not offer enough detail for treatment planning, CBCT may be used to assess the fracture's position, severity, and orientation.

Displaced segments should be repositioned. Stabilization of the segment by splinting the involved teeth with a passive and flexible splint for 4 weeks should be performed. If present, lacerations of the gingiva should be sutured.

Initiating endodontic treatment at the emergency visit is contraindicated. Pulp vitality of all affected teeth must be monitored during both the initial assessment and follow-up appointments to determine whether and when endodontic treatment is required (Bourguignon et al., 2020).

4.2. Injuries to the Supporting Structures

4.2.1. Concussion

Concussion is a mild injury to the periodontal ligament that does not result in tooth displacement or unusual mobility (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007). This type of supporting tissue injury leads to pronounced sensitivity to percussion, though the tooth remains stable and properly positioned. Mobility is within normal limits. The tooth is sensitive to percussion and touch. It usually responds positively to pulp sensitivity testing. No radiographic abnormalities are detected.

A parallel periapical radiograph is the first-line imaging recommendation, with additional views warranted only if clinical signs or symptoms suggest other injuries. No immediate treatment is required. The pulpal status should be carefully monitored for at least one year, and preferably longer (Bourguignon et al., 2020).

4.2.2. Subluxation

Subluxation is a periodontal ligament injury in which the tooth is not displaced but exhibits increased mobility. Although damage to the pulp circulation and periodontal tissues is minor, pulpal complications are frequently encountered.

The tooth typically presents with sensitivity to touch and percussion. Increased mobility is present, but the tooth remains in its original position. Bleeding from the gingival sulcus may be observed during examination.

The tooth might show no reaction to pulp vitality tests in the early phase due to transient pulp injury. Radiographic findings are generally normal.

Recommended imaging includes a parallel periapical radiograph, two supplementary views from varying vertical and/or horizontal angles, and an occlusal radiograph.

Typically, no treatment is necessary. However, if excessive mobility or sensitivity during biting is present, the tooth may be stabilized using a passive and flexible splint for up to 2 weeks.

The pulp status should be monitored for at least a year, and best for longer (Bourguignon et al., 2020).

4.2.3. Lateral Luxation

This injury involves displacement of the tooth along its long axis, typically with the apical portion displaced labially and the coronal portion displaced palatally. Pulpal blood supply is usually completely disrupted (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007).

Tooth displacement most often occurs toward the labial or palatal/lingual side. An associated alveolar bone fracture is frequently present. Because the apex is “locked” in place by the fractured bone, the tooth is often immobile.

Percussion often results in a sharp, metallic tone suggestive of ankylosis, and the tooth usually does not respond to pulp sensitivity tests.

Widening of the periodontal ligament space may be visible, most distinctly on horizontally angled or occlusal radiographs. Recommended imaging includes a parallel periapical radiograph, two additional views from different vertical and/or horizontal angles, and an occlusal radiograph.

Under local anesthesia, the tooth should be softly repositioned by removing it from its locked position using finger pressure.

Technique:

Palpate the gingiva to locate the position of the root apex. Pressure application should be done with a single finger apically to disengage the apex, and with another finger or thumb, the crown should be pushed back into the socket.

Support the tooth with a passive, flexible splint for 4 weeks.

If there is marginal bone loss or a bone fracture, a longer splinting period may be required.

During follow-up, pulp sensitivity tests should be conducted to monitor pulp vitality.

Approximately 2 weeks after the injury, the following endodontic evaluations should be performed (Bourguignon et al., 2020).

4.2.3.1 Teeth with Incomplete Root Development

Spontaneous revascularization is possible; however, if pulp necrosis occurs and infection-related external root resorption develops, root canal treatment should be started promptly. At that stage, endodontic protocols specific to immature teeth should be followed.

4.2.3.2 Teeth with Complete Root Development

Pulp necrosis is highly probable. To avoid the onset of inflammatory external root resorption, root canal therapy should be promptly initiated using an intracanal medicament, such as a corticosteroid-antibiotic paste or calcium hydroxide (Bourguignon et al., 2020).

4.2.4. Intrusive Luxation

Intrusion is considered the most severe form of luxation, characterized by the tooth being pushed directly into the socket toward the apex. This results in crushing of the neurovascular bundle entering the pulp and causes severe damage to the cementum and periodontal ligament.

The tooth is displaced into the alveolar bone along its long axis and is immobile.

Percussion testing produces a high-pitched, metallic sound suggestive of ankylosis. The tooth usually shows no response to pulp sensitivity tests.

The periodontal ligament space is partially or completely obliterated, particularly in the apical region.

In intruded teeth, the cementoenamel junction (CEJ) is more apically located compared to adjacent, uninjured teeth.

Recommended imaging consists of a parallel periapical radiograph, two supplementary views taken at varying vertical and/or horizontal angles, and an occlusal radiograph

(Bourguignon et al., 2020).

4.2.4.1. Teeth with Incomplete Root Development (Immature Teeth)

Despite the level of intrusion, all intruded teeth should initially be left for spontaneous re-eruption. If re-eruption does not occur within 4 weeks, orthodontic repositioning should be initiated. Pulpal status should be closely monitored. In teeth with incomplete root development, spontaneous pulp revascularization is possible. However, if clinical or radiographic signs of pulp necrosis, infection, or inflammatory (infection-related) root resorption are observed during follow-up—and if the position of the tooth permits—root canal treatment should be initiated promptly. Endodontic protocols specific to immature teeth should be followed, and parents must be advised on the critical importance of attending follow-up visits (Levin et al., 2020).

4.2.4.2. Teeth with Complete Root Development (Mature Teeth)

When intrusion does not exceed 3 mm, allow spontaneous re-eruption. If re-eruption does not occur within 8 weeks, perform surgical repositioning and splint the tooth for 4 weeks. As an alternative, orthodontic repositioning may be initiated prior to ankylosis development. If the intrusion is between 3–7 mm, reposition the tooth—preferably via surgical or orthodontic methods. If the intrusion exceeds 7 mm, surgical repositioning is indicated.

In mature teeth, the pulp is highly likely to become necrotic. Root canal therapy should begin by the second week or once the tooth can be properly accessed.

An intracanal medicament such as a corticosteroid-antibiotic paste or calcium hydroxide should be used to prevent inflammatory (infection-related) external root resorption (Bourguignon et al., 2020).

4.2.5. Extrusive Luxation

This injury consists of the displacement of the tooth in a coronal direction along its vertical axis, affecting the periodontal supporting structures and disrupting the pulp's blood supply (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007).

The tooth appears elongated (typically extruded in the incisal direction). Increased mobility is present. The tooth is unlikely to be responsive to pulp sensitivity tests.

The periodontal ligament space appears widened in both apical and lateral directions. The tooth may appear "suspended" and not fully seated in the socket, with visible extrusion coronally.

Radiographic recommendations:

- One parallel periapical radiograph
- Two additional radiographs taken from different vertical and/or horizontal angles
- An occlusal radiograph

Under local anesthesia, the tooth should be gently repositioned into the socket.

Use a passive, flexible splint to stabilize the tooth for 2 weeks.

If marginal bone loss or fracture is present, splinting should be extended for an additional 4 weeks.

Pulp vitality should be monitored through sensitivity testing.

If pulp necrosis and infection develop, endodontic treatment suitable for the tooth's stage of root development should be initiated (Bourguignon et al., 2020).

4.2.6. Avulsion

Avulsion of permanent teeth occurs in approximately 0.5–16% of all dental injuries (J.O.Andreasen, F.M.Andreasen, L.Andersson. 2007; Fouad et al., 2020; Glendor et al., 1996).

Numerous studies have established this as one of the most severe forms of dental trauma, with its prognosis largely influenced by the specifics of the incident and the promptness of initial management after avulsion.

Replantation is the preferred treatment in most cases, although it is not always possible to perform immediately.

For favorable outcomes, timely emergency care and a well-structured treatment plan are crucial.

There are individual cases where replantation is not indicated, such as:

- Numerous caries or periodontal disease
- Non-cooperative patients
- Severe mental impairment requiring the use of sedation
- Immunosuppression or advanced cardiac conditions

Even though replantation may not ensure long-term survival, it is important to recognize that opting against replantation of the tooth is an irreversible decision. Replantation should be attempted if possible.

Recent studies have shown that teeth replanted in accordance with IADT guidelines have higher survival rates compared to earlier reports (Fouad et al., 2020).

Treatment Guidelines for Avulsed Permanent Teeth

Treatment selection varies depending on:

- Stage of root development (open or closed apex)
- Periodontal ligament (PDL) cell's condition
- This condition is directly affected by how long the tooth remained dry outside the mouth and the type of storage medium used.

Critical point: PDL cell viability significantly declines after 30 minutes of dry storage.

PDL cell status scenarios:

- PDL cells are likely viable:
- Replantation was done right away or within 15 minutes after the injury.
- PDL cells may still be viable, though their survival remains uncertain:
- The tooth was stored in an appropriate medium (such as milk, HBSS, saliva, or saline), and the total dry time did not exceed 60 minutes.
- PDL cells are non-viable:
- The tooth remained dry or was stored in a medium, but the total dry time exceeded 60 minutes.
- (Fouad et al., 2020)

Splinting in Dental Trauma

Splinting is a widely used technique to stabilize and reposition traumatized teeth.

A splint is defined as a device used to support, protect, or immobilize loosened, repositioned, fractured, or surgically treated teeth (McClanahan et al., 2020).

Historically, rigid splints were used based on bone fracture management principles. However, rigid immobilization can lead to pulpal necrosis and external root resorption.

Today, flexible splints are preferred due to their lower ankylosis risk and allowance for slight physiological tooth movement (Eranhikkal & Goswami, 2020).

Ideal Requirements of a Splint

(as modified from Andreasen, 1972):

- Allow reattachment of periodontal ligament fibers
- Prevent further trauma or aspiration of mobile teeth
- Easy to apply and remove without soft tissue trauma
- Maintain teeth in correct position during the splinting period
- Permit physiological mobility
- Avoid soft tissue irritation
- Permit vitality testing and endodontic access
- Allow sufficient oral hygiene
- Does not interfere with occlusion
- Be aesthetically acceptable and comfortable for the patient
- (Eranhikkal & Goswami, 2020)

Common Splint Types

- **Composite and Stainless Steel Wire Splints**

  If the wire diameter is ≤0.4 mm, it is considered flexible.

  They are less irritating to gingival tissues and effective for luxation and avulsion injuries.

  Placement is simple, non-traumatic to adjacent teeth, and allows easy hygiene and aesthetic maintenance.

  These splints allow pulp vitality testing and endodontic procedures.

- **Fiber Splints**

Made from polyethylene or Kevlar mesh (e.g., Ribbond™, Fiber-Splint™, EverStick™).

Used with unfilled resin (e.g., Optibond FL™).

Offer good stabilization, aesthetic acceptability in children, are easy to apply, and cause no trauma to soft tissues.

They do not interfere with vitality testing or endodontics, and support oral hygiene.

- **Arch Bar Splints**

  Metal bars contoured to the dental arch and fixed with ligature wires.

  Major drawback: rigidity and lack of physiological movement.

  Can cause gingival irritation and are no longer commonly used in dental trauma management—except for dentoalveolar fractures.

- **Acrylic Splints**
- Indicated in complex cases with associated bone fractures, especially in pediatric or adolescent patients.
- Useful in conservative management when surgical intervention is to be avoided.

Conclusion

- After luxation or avulsion injuries, splinting is essential during the acute phase to ensure stability.
- According to IADT guidelines, semi-rigid or flexible splints are preferred over rigid ones to avoid complications like root resorption or ankylosis.
- Traditional splinting techniques may not be aesthetically acceptable in pediatric patients.
- Newer composite-based splints improve patient cooperation and outcome.
- Regular follow-up is critical to prevent long-term trauma-related complications.

- (Eranhikkal & Goswami, 2020)

4.2.6.1. Treatment Guidelines for Avulsed Permanent Teeth with Closed Apex

The tooth was replanted at the accident site or before the patient arrived at the clinic.

- Rinse the affected area using saline, water, or chlorhexidine.
- Check the position of the replanted tooth both radiographically and clinically.
- Leave the tooth/teeth in current position unless malpositioned. If the replantation is incorrect, the tooth's position should be gently corrected using finger pressure.
- If necessary, administer local anesthesia, idelly without vasocons-trictors.
- If the tooth has been placed in a different socket or has been mispo-sitioned, it can still be repositioned correctly within 48 hours fol-lowing the injury.
- Support the tooth with a passive and flexible splint made of 0.016-inch (or 0.4 mm) diameter wire, bonded to adjacent teeth for 2 weeks.
- Avoid placing composite or bonding materials near the gingiva or in proximal areas.
- Alternatively, nylon fishing line (0.13 inch or 0.25 mm diameter) bonded with composite may be used as a flexible splint.
- However, nylon splints are not advised for children with only a few permanent teeth, as there is an increased risk of the splint be-coming dislodged or lost during this stage of development.
- If the injury is accompanied by alveolar or jaw fracture, a firmer splint is recommended and should remain in place for around four weeks.
- Suture any soft tissue lacerations, if available.
- Following replantation, initiate endodontic treatment within 2 we-eks.
- Systemic antibiotics should be prescribed.
- Tetanus immunization status should be verified.

- Give postoperative care instructions.
- Schedule and emphasize the importance of follow-up visits.
- (Fouad et al., 2020)

Management of Avulsed Tooth Stored in a Physiologic or Non-Physiologic Medium with Extra-Oral Dry Time Less Than 60 Minutes

- Physiologic storage media consist of culture mediums and cell transport solutions. Osmotically balanced options include milk and Hank's Balanced Salt Solution (HBSS).
- If there is visible contamination, rinse the root with saline or an osmotically balanced solution to remove any debris.
- Check for deposits or debris on the avulsed root surface.
- Gently agitate the tooth in the storage medium to loosen debris.
- Alternatively, briefly rinse the root with sterile saline.
- While taking the history, conducting clinical and radiographic examinations, and preparing the patient for replantation, keep the tooth in a suitable storage medium.
- Administer local anesthesia, ideally without vasoconstrictors.
- Cleanse the socket with sterile saline.
- Perform alveolar socket examination.
- If a socket wall fracture is present, reposition the fractured fragment using an appropriate instrument.
- Removing the blood clot from the socket via saline irrigation may help ensure optimal tooth positioning.
- Gently replant the tooth into the socket using light finger pressure.
- The tooth must not be forcebly pushed into position.
- Verify the placement of the replanted tooth through both clinical examination and radiographic imaging.
- Stabilization of the tooth should be done using a passive and flexible splint such as a 0.016-inch (0.4 mm) wire bonded to adjacent teeth for 2 weeks.
- Avoid placing composite or bonding agents on the gingival margins or proximal surfaces.

- Alternatively, nylon fishing line (0.13 inch or 0.25 mm diameter) may be used as a flexible splint.
- However, nylon splints are not advised for children who have only a limited number of permanent teeth, as they may not provide adequate stability.
- Suture any soft tissue lacerations, if present.
- Begin root canal therapy within two weeks of replantation.
- Prescribe systemic antibiotics.
- Verify tetanus immunization status.
- Provide the patient with postoperative care instructions.
- Schedule and emphasize follow-up appointments.
- (Fouad et al., 2020)

Avulsed Tooth with Open Apex – Extra-Oral Dry Time > 60 Minutes

- To clear loose debris and visible contaminants, gently swirl the tooth in a physiologic storage solution, or wipe the root surface with gauze moistened with sterile saline.
- While taking the patient history, conducting clinical and radiographic examination, and preparing for replantation, keep the tooth in a suitable storage medium.
- Administer local anesthesia, ideally without vasoconstrictors.
- Cleanse the socket with sterile saline.
- Examine the alveolar socket.

    If a blood clot is present, remove it gently.

    If a socket wall fracture is detected, adjust the bone fragment into place with the proper instrument.

- Replant the tooth slowly using light finger pressure.

    Do not force the tooth into the socket.

- Confirm the position of the replanted tooth radiographically and clinically.
- Stabilize the tooth using a passive flexible splint (0.016 inch or 0.4 mm wire) bonded to adjacent teeth for 2 weeks.

Avoid placing bonding materials on gingival margins or proximal surfaces.

Alternatively, nylon monofilament line (0.13 inch or 0.25 mm) may be used as a flexible splint.

If the injury is associated with alveolar or jaw fracture, a more rigid splint is indicated for approximately 4 weeks.

- Suture any soft tissue lacerations if existing.
- Within 2 weeks, initiate root canal treatment.
- Prescribe systemic antibiotics.
- Verify tetanus immunization status.
- Provide the patient with postoperative care instructions.
- Schedule and emphasize the importance of follow-up visits.

Prognosis:

Delayed replantation is associated with an unfavorable long-term results. The periodontal ligament typically becomes necrotic and fails to regenerate.

The expected outcome is replacement resorption (ankylosis).

However, the purpose of replantation in such cases is to preserve alveolar bone contour, width, and height, and to temporarily restore esthetics and function.

Therefore, replantation is typically the right choice, even if the tooth has been dry outside the mouth for over 60 minutes, as this maintains future treatment options, and the tooth may be removed later following a multidisciplinary assessment.

It is important to inform patients that depending on the child's growth, the replanted tooth may ankylose or remain in infraocclusion, requiring decoronation, autotransplantation, or eventual extraction.

Ankylosis and resorption rates can vary greatly and are difficult to predict. (Fouad et al., 2020).

4.2.6.2. Treatment Protocols for Avulsed Permanent Teeth with Open Apices

Tooth Replanted Before Arrival at the Clinic

- Verify the position of the replanted tooth through clinical examination and radiographic imaging.
- Keep the tooth in its present position, unless improperly positioned, in which case it should be gently repositioned using light finger pressure.
- If necessary, administer local anesthesia, ideally without vasoconstrictors.
- If the tooth has been placed in the wrong socket or with improper rotation, repositioning can be attempted up to 48 hours after the injury.
- Support the tooth with a flexible, non-rigid splint (0.016 inch or 0.4 mm wire) attached to adjacent teeth for two weeks.

  Short immature teeth might need extended splinting durations.

  Avoid using bonding agents or composite close to the gingival margin or interproximal spaces.

  Nylon fishing line (0.13 inch or 0.25 mm) bonded with composite can also be used.

  If an alveolar or jaw fracture is present, a rigid splint is recommended for about 4 weeks.
- Suture any soft tissue lacerations.
- The primary goal in replantation of immature teeth in children is to facilitate further root development via pulpal revascularization.

  The possibility of inflammatory root resorption should be carefully balanced with the chance of revascularization. This type of resorption progresses rapidly in children.

  If revascularization fails to occur and signs of pulp necrosis or infection are present, proceed with apexification, pulp revitalization, or conventional root canal therapy.
- Prescribe systemic antibiotics.
- Provide post-operative care instructions.
- Schedule follow-up appointments.
- In immature teeth with open apices, spontaneous healing may occur via new connective tissue with vascular support, enabling continued root development and maturation.

Therefore, do not initiate endodontic treatment unless clear signs of pulpal necrosis or infection are present (Fouad et al., 2020).

Tooth Stored in Physiologic or Non-Physiologic Conditions, Extra-Oral Dry Time < 60 Minutes

- Preserve the tooth in an appropriate medium while taking history and preparing for replantation.
- Use a vasoconstrictor-free local anesthetic.
- Cleanse the socket with sterile saline.
- Crefully inspect the socket; reposition bone fragments if socket wall is fractured.
- Carefully place the tooth back into its socket with gentle pressure.
- Confirm tooth position clinically and radiographically.
- Splint passively with 0.016-inch (0.4 mm) wire or 0.13–0.25 mm nylon for 2 weeks.
- Use rigid splint for 4 weeks if alveolar/jaw fracture is present.
- Suture soft tissue if needed.
- Aim for pulp revascularization; if signs of necrosis appear, initiate appropriate endodontic treatment.
- Prescribe antibiotics and assess tetanus status.
- Provide post-op care and schedule follow-up.
- (Fouad et al., 2020)

Extra-Oral Dry Time > 60 Minutes

- Rinse the tooth gently in storage medium or saline to remove debris.
- Keep the tooth in a suitable medium until replantation.
- Administer vasoconstrictor-free anesthetic for pain management-Rinse the socket using sterile saline.
- Reposition bone fragments if socket wall is fractured.
- Replant the tooth patiently using soft finger pressure.
- Verify position clinically and radiographically.

- Splint passively with wire or nylon for 2 weeks; use rigid splint if bone fracture is present.
- Suture if necessary.
- Aim for pulpal revascularization; if it fails, start endodontic treatment based on clinical/radiographic signs.
- Prescribe antibiotics and assess tetanus status.
- Provide post-op care and schedule follow-up.

Note on Prognosis: Although prognosis is poor due to likely PDL necrosis and risk of replacement resorption, replantation is still recommended to preserve alveolar ridge contour and function, even if temporary. Inform parents about potential ankylosis, infraocclusion, and the possibility of future procedures (e.g., decoronation, autotransplantation) depending on growth.

(Fouad et al., 2020)

4.3. Endodontic Considerations

In case of endodontic treatment indication (i.e., in teeth with closed apices), replantation should be followed with therapy within 2 weeks

(Day, Duggal, & Nazzal, 2019; Fouad et al., 2020).

Endodontic procedures must always be performed under rubber dam isolation. To prevent further trauma to the injured tooth/teeth, the rubber dam clamp should be placed on adjacent, non-injured teeth whenever possible.

As an intracanal medicament, calcium hydroxide is recommended for a period of up to one month prior to final root canal filling (Andreasen, Farik, & Munksgaard, 2002; Rosenberg, Murray, & Namerow, 2007).

When using an anti-inflammatory or anti-resorptive medicament, such as a corticosteroid or a corticosteroid–antibiotic combination, it should be introduced shortly after replantation—ideally immediately—and maintained in the canal for a minimum of six weeks

(Bryson et al., 2002; Chen et al., 2008; Day et al., 2012).

These medicaments must be applied carefully within the root canal system, ensuring they do not come into contact with the crown, as some agents have been associated with discoloration and aesthetic dissatisfaction

(Day et al., 2011).

Occurence of spontaneous revascularization is prevelant in tooth with open apices. Therefore, endodontic therapy should be postponed unless follow-up visits show definitive clinical or radiographic evidence of pulp necrosis or infection.

The likelihood of inflammatory, infection-related root resorption should be carefully balanced against the potential for pulpal revascularization—particularly in children, where this type of resorption can advance quickly.

Once pulpal necrosis and root canal infection are diagnosed, the treatment plan should consist of the following steps:

- root canal obturation,
- apexification, or
- pulpal revascularization/revitalization.

Where ankylosis and eventual decoronation are expected, the choice of intracanal materials should align with this outcome and the planned treatment

(Fouad et al., 2020).

4.3.1. Revascularization Treatment

In immature permanent teeth with necrotic pulp and disrupted pulpal circulation due to avulsion, the ideal treatment to support continued root development and maturation of dentin walls is revascularization therapy, which aims to restore pulp vitality, thereby allowing regeneration and repair of the pulp-dentin complex.

Revascularization is a biologically based endodontic procedure that re-establishes vascularity within the pulp space of necrotic immature teeth, promoting continuity of root development and healing of apical periodontitis in the affected area.

For revascularization therapy to be successful, it is crucial that the vital tissues present at the apical segment of the immature root remain undamaged. Therefore, irrigating solutions play a key role in disinfection.

These irrigants must offer maximum antimicrobial efficacy, while maintaining minimal cytotoxicity to support the viability and proliferation of stem cells and fibroblasts (Yılmaz et al., 2016).

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