

Dental Trauma and Its Management: A Comprehensive Review of Current Practices and Challenges

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Abstract

Dental trauma is a significant public health concern impacting individuals across all age groups, with particular prevalence among children and adolescents. This review highlights current advances, including the use of cone-beam computed tomography for precise diagnosis, bioceramic materials for endodontic treatments, and AI-driven tools for enhanced clinical decision-making. Restorative techniques employing composite resins and 3D printing technologies have improved treatment outcomes, particularly for complex injuries. Additionally, leveraging telehealth and advanced technologies can help bridge gaps in care, particularly in underserved and rural areas. However, challenges persist, including diagnostic complexity, inconsistent adherence to guidelines, and limited provider training. Addressing these issues through preventive strategies, public education, and multidisciplinary collaboration is crucial for reducing the burden of dental trauma.

Introduction

Dental trauma is a prevalent issue that affects individuals of all ages, often resulting in significant physical, psychological, and financial impacts. Traumatic dental injuries (TDIs) may involve the teeth, periodontal tissues, alveolar bone, or oral soft tissues. The management of dental trauma requires an interdisciplinary approach to restore function, aesthetics, and oral health (Al-Sunbul et al., 2024). It is a significant global public health issue, impacting individuals of all ages, though it is most common in children and adolescents. The prevalence of dental trauma and its associated complications varies widely across populations, depending on factors such as age, gender, socioeconomic conditions, and the availability of preventive measures. Recent studies highlight that dental trauma is alarmingly common, particularly in children and young adults. For instance, a study conducted in Ha'il, Saudi Arabia, found a prevalence of 44%, with boys aged 6–9 being most affected, often due to falls at home (Alshammmary et al., 2022). Similarly, a meta-analysis revealed an overall prevalence of 19.48%, with substantial variations based on demographic and geographic factors (Tysi c-Mi sta et al., 2024). Dental trauma prevalence among children aged 6–12 was reported at 18.2% in a study conducted in Mexico, with falls and collisions being common causes (Rueda-Ibarra et al., 2022). A study in Egypt highlighted that males and children with developmental disabilities are particularly vulnerable (Abbass et al., 2024).

The nature of dental injuries often depends on the affected dentition. For primary teeth, luxation injuries and crown discoloration are prevalent complications (Mocellini et al., 2022). For permanent teeth, fractures of the upper central incisors are the most frequent injuries, often resulting from falls or sports activities (Lembacher et al., 2022). In children, untreated traumatic injuries, particularly those involving fractures and luxation, can lead to functional, aesthetic, and psychological issues, highlighting the importance of early and effective management. Complications of dental trauma include pulp necrosis, periapical radiolucency, root resorption, and premature tooth loss. A systematic review found that crown discoloration and pulp necrosis were the most common

sequelae, with prevalence rates of 39.7% and 24.3%, respectively (**Moccelini et al., 2022**). Severe cases may lead to ankylosis and abscess formation, further complicating treatment and prognosis. Dental trauma remains a prevalent and under-addressed issue with long-term consequences for oral health. Improved preventive strategies, timely interventions, and public awareness are critical to mitigating its impact and reducing associated complications. Preventive strategies such as public education, the use of mouthguards, and targeted awareness campaigns can significantly reduce the incidence and severity of dental injuries (**De Lima et al., 2024**). This review highlights the current practices, challenges, and advancements in the field of dental trauma management.

1. Management of Dental Trauma

a. Soft Tissue Injuries

Soft tissue injuries in dental trauma, including lacerations, abrasions, and contusions, often occur alongside dental injuries. The accurate diagnosis of soft tissue injuries is critical for effective management. Proper management is critical to prevent complications such as infection, scarring, and functional impairments (**Moule & Cohenca, 2016**). These injuries require comprehensive assessment, including a detailed history, physical examination, and radiographic imaging when necessary. Soft tissue injuries can harbor embedded foreign materials, including tooth fragments, which may complicate healing if left untreated. For example, Al-Jundi (2010) described a case where a tooth fragment embedded in the lower lip went unnoticed for 18 months due to inadequate examination (**Al-Jundi, 2010**). Similarly, Çubukçu et al. (2011) highlighted a case where delayed removal of a primary incisor embedded in the lip still resulted in a favorable outcome after surgical intervention, underlining the necessity of radiographic evaluation during the acute phase (**Cubukcu et al., 2011**). Effective management of soft tissue injuries involves debridement, suturing (if necessary), and prevention of infection. Ensuring tetanus prophylaxis is also crucial. Proper cleaning and removal of necrotic tissue are essential to prevent infection. Irrigation with sterile solutions and thorough debridement are also foundational steps (**Sjamsudin et al., 2020**). Closure of wounds using sutures, particularly in lacerations, promotes faster healing and restores aesthetics. Special techniques may be required for complex injuries in the maxillofacial region (**Septian et al., 2023**).

Postoperative care is equally important for managing soft tissue injuries. It includes administering antibiotics to prevent infection, providing pain relief, and maintaining proper hydration and moisture at the wound site. Sjamsudin et al. (2020) highlighted that close monitoring of the wound for signs of infection or dehiscence is critical for successful outcomes (**Sjamsudin et al., 2020**). Innovations in wound management, such as using phototherapy for tissue healing and pain control, have also been introduced, providing additional tools for clinicians (**Nardi et al., 2021**). In some cases, advanced methods like electrosurgery or laser therapy can be used to manage subgingival injuries and facilitate tissue healing (**Roocroft & Srinivasan, 2024**).

Complex cases of soft tissue trauma may require advanced interventions. For instance, Roocroft and Srinivasan (2024) discussed the use of electrosurgery to manage subgingival soft tissue injuries in pediatric patients, allowing for better access during restorative procedures (**Roocroft & Srinivasan, 2024**). Moreover, managing soft tissue injuries in dental trauma involves addressing both functional and aesthetic concerns. Braun and Maricevich (2017) emphasized the unique challenges posed by facial aesthetics, noting the importance of tailored approaches depending on the injury's location and severity (**Braun & Maricevich, 2017**).

b. Hard Tissue Injuries

The management of hard tissue injuries in dental trauma involves a systematic approach that includes diagnosis, treatment planning, and rehabilitation to ensure both functional and aesthetic restoration. Hard tissue injuries, such as enamel or crown fractures, luxation, and avulsion, require prompt intervention to optimize outcomes. The International Association of Dental Traumatology (IADT) guidelines stress the importance of timely care, emphasizing that immediate management can significantly improve prognosis, particularly for fractures and luxations (**Bourguignon et al., 2020**). For enamel and crown fractures, conservative treatments, such as reattachment of fragments using adhesive systems, are preferred. These methods preserve the tooth structure and restore aesthetics effectively. Advanced techniques, including the use of dentin bonding systems, have improved outcomes for crown fractures, even those involving the pulp (**Andreasen et al., 2019**). Furthermore, the use of flexible splints to stabilize teeth after luxation or fractures involving the alveolar bone has been a cornerstone in trauma management. Innovations in diagnostic tools and biomaterials have improved the management of hard tissue injuries. Cone beam computed tomography (CBCT) is increasingly used for detailed evaluation of fractures and root injuries, aiding in precise treatment planning (**Reddy et al., 2019**). The use of bioactive materials like mineral trioxide aggregate (MTA) in pulpotomy or pulp capping procedures enhances the success rate of preserving pulp vitality. Endodontic treatment is often indicated when pulp vitality is compromised. Techniques such as apexification and apexogenesis are critical for managing immature teeth to allow root development, ensuring long-term retention. For more severe injuries like avulsion, the IADT recommends replantation and splinting, provided the periodontal ligament can be preserved. Timely endodontic treatment, typically within 7–10 days, is crucial to mitigate the risk of

resorption (**Krastl et al., 2021**). For root fractures, proper reimplantation and stabilization using flexible splints are critical. Immediate reimplantation of avulsed teeth is recommended, ideally within 30 minutes of the injury. Delay in reimplantation increases the risk of root resorption (**Andersson et al., 2012**). New guidelines recommend maintaining splints for 4 weeks in middle-third fractures and up to 4 months in cervical fractures (**Vaswani et al., 2020**). Splinting techniques, using flexible or semi-rigid splints for 1–4 weeks, are critical for stabilizing luxated teeth (**Goswami & Eranhikkal, 2020**). Advances in radiographic imaging, such as cone-beam computed tomography (CBCT), facilitate precise diagnosis and monitoring. Luxation Injuries including concussion and subluxation typically resolve without invasive treatment. Monitoring pulp vitality over time is critical. However, in case of extrusion, lateral luxation, and intrusion, the treatment varies based on severity. Repositioning is often required, followed by stabilization with splinting. For intruded teeth, orthodontic extrusion or surgical repositioning might be necessary (**Sule et al., 2024**). Avulsion presents unique challenges. Immediate replantation is ideal; however, if delayed, keeping the tooth in a suitable storage medium (milk, Hank's Balanced Salt Solution, or saline) is crucial to preserving periodontal ligament (PDL) cell viability (**De Brier et al., 2020**). Updated IADT guidelines emphasize the importance of reducing extra-alveolar dry time to less than 60 minutes (**Chappuis & Von, 2005**). Antibiotic prophylaxis and splinting for 2 weeks follow replantation (**Fouad et al., 2020**).

2. Advanced Current Practices in Management of Dental Trauma

With recent advancements in diagnostic tools, biomaterials, and treatment protocols, there have been significant improvements in the outcomes of dental trauma management. Recent advancements in diagnostic tools like cone beam computed tomography (CBCT) (**Kim et al., 2017**), biomaterials such as mineral trioxide aggregate (MTA) (**De Oliveira et al., 2018**), and evidence-based treatment protocols have revolutionized dental trauma management. These innovations enhance precision in diagnosis, promote effective healing, and improve functional and aesthetic outcomes, offering patients a higher standard of care and long-term success.

a. Improved Diagnostic Methods

Accurate diagnosis is the cornerstone of effective dental trauma management. Traditionally, radiographs such as periapical and panoramic X-rays were the primary tools for diagnosing the extent of injury (**Patel et al., 2021**). However, with technological advancements, new diagnostic methods are now available. CBCT has revolutionized the way dental trauma is diagnosed. Unlike conventional 2D radiographs, CBCT provides a 3D view of the injured area, enabling precise visualization of fractures, luxations, and other bone injuries. Studies have shown that CBCT is especially valuable for evaluating root fractures, tooth displacements, and alveolar fractures that may not be clearly visible on traditional radiographs. This imaging technique also allows for better planning of surgical interventions, including repositioning of teeth after avulsion or luxation (**Alshomrani, 2024**). For more accurate and efficient assessment, intraoral scanning has become an integral part of dental trauma management, particularly in creating precise digital impressions of the injured teeth. These digital impressions assist in fabricating customized splints or prosthetic restorations and provide superior fit compared to conventional molds (**Zarbakhsh et al., 2021**).

b. Use of Bioceramic Materials for Pulp and Root Treatment

The management of pulp involvement in dental trauma has seen considerable innovation in recent years. When trauma leads to pulp exposure, the traditional approach has been root canal therapy. However, modern bioceramic materials have significantly improved the outcomes of these procedures. Mineral Trioxide Aggregate (MTA) has become the material of choice for pulp capping and root-end sealing procedures. It is biocompatible, promotes healing, and helps in the regeneration of damaged pulp tissue (**Daniele, 2017**). Recent studies show that MTA leads to better outcomes in terms of sealing and reduced infection rates when compared to traditional materials like calcium hydroxide (**Dong & Xu 2023**). Bioceramic materials are also used in regenerative endodontic procedures. These materials promote pulp regeneration and help in the healing of the pulp and periodontal tissues. Research suggests that bioceramics provide a better prognosis, particularly in immature teeth, by enhancing the natural healing processes (**Raghavendra et al., 2017**). Regenerative endodontics also known as pulp regeneration, involves the revascularization of the pulp tissue in cases of necrotic pulp following trauma (**Saad et al., 2024; Kahler & Lin, 2017**). Techniques such as stem cell therapy and the use of bioactive scaffolds are being explored to regenerate the pulp tissue, especially in young, immature permanent teeth (**Li et al., 2024**). These treatments hold the potential to restore normal pulp function and extend the life of the tooth.

c. Advanced Restorative Techniques for Tooth Fractures

Managing fractures that involve both the crown and root requires precision and effective restorative techniques. Modern restorative dentistry focuses on using advanced materials that not only restore the tooth's structure but also enhance its function and aesthetics. Advances in dental composite materials have made them the treatment of choice for restoring fractured teeth. Composite resins are strong, durable, and can be seamlessly matched to the natural tooth color. They are often used in managing crown fractures, where the tooth structure has been compromised but the pulp remains intact (**Ahmed et al., 2022**). The development of nanocomposites has further improved the

aesthetic and functional qualities of restorations (**Mandhalkar et al., 2023**). In more severe fractures or when cosmetic restoration is a priority, ceramic materials such as lithium disilicate are preferred due to their strength and natural appearance. These materials are especially useful for managing complex crown-root fractures, where the tooth needs both structural reinforcement and aesthetic restoration (**Vervack et al., 2024**). The use of 3D printing for technology has significantly impacted restorative dental practices. 3D printers can create highly accurate models of the fractured teeth, which can then be used to design custom crowns or splints. This technique is particularly useful for creating immediate restorations or temporary solutions following trauma, allowing for faster recovery and reducing the need for multiple appointments (**Rezaie et al., 2023**).

d. Digital Technology and Artificial Intelligence (AI) Integration

Digital technologies, such as 3D printing and artificial intelligence (AI), have revolutionized the management of dental trauma by making the process more efficient and precise. 3D printing technology is revolutionizing dentistry by enabling the rapid design and fabrication of customized dental splints, prosthetics, and components, enhancing precision and patient comfort. It facilitates the creation of personalized dental splints and prosthetics that are biocompatible, efficient, and stable. These devices can be produced quickly using digital workflows, reducing time and material costs compared to traditional methods (**Sayed et al., 2024**). Moreover, it allows for precise fabrication of dental prosthetics and surgical guides. Innovations in materials ensure biocompatibility and durability, contributing to higher patient satisfaction (**Dhull, 2023**). Thermoflexible occlusal splints, created with 3D printing, also offer superior elasticity and patient comfort. These innovations enhance compliance, especially for treating conditions like bruxism and temporomandibular joint disorders (**Harichane, 2023**). 3D printing in maxillofacial surgery aids in fabricating accurate surgical guides and anatomical models. These applications enhance surgical planning, reducing intraoperative time and improving outcomes (**Louvrier et al., 2017**). The use of 3D printing for orthodontic appliances, such as clear aligners and surgical splints, has also streamlined workflows while increasing customization and treatment precision (**Konda & Rafiq, 2024**). Moreover, in rural or resource-limited settings, 3D printing has been shown to produce custom prosthetics and splints, improving accessibility to personalized medical aids and significantly reducing costs (**Van der Stelt et al., 2020**).

AI-powered diagnostic tools are significantly advancing the field of dental trauma identification and treatment planning, particularly through the analysis of radiographs. These technologies enhance diagnostic precision and reduce clinical workload. AI tools have demonstrated exceptional accuracy in detecting and segmenting teeth on panoramic radiographs, achieving a sensitivity of 98.9% and precision of 99.6%, thereby significantly reducing manual effort by 67% (**Leite et al., 2020**). AI systems trained on cone-beam computed tomography (CBCT) data and panoramic radiographs enable precise assessments of root resorption. Their ability to analyze angulation and segmentation maps of molars supports predictions about third molar eruption potential (**Vranckx et al., 2020**). High-accuracy AI systems trained with extensive datasets can screen for oral pathologies such as dental caries, periapical lesions, and missing teeth, assisting in broad-scale oral health assessments (**Turosz et al., 2024**). AI-driven dental imaging systems use predictive modeling to forecast disease progression and improve treatment planning. This streamlines clinical workflows and reduces human error, offering a transformative approach to diagnostics (**Kale et al., 2024**). Moreover, deep learning models have shown a mean average precision of up to 0.973 for detecting dental restorations, implants, and dentures on panoramic radiographs, suggesting their reliability for integration into clinical practice (**Çelik & Çelik, 2022**).

3. Challenges in Dental Trauma Management

Dental trauma management poses numerous challenges that impact clinicians, patients, and healthcare systems alike. These challenges encompass the complexity of diagnosis, variability in treatment approaches, insufficient knowledge and training among healthcare providers (**Elendu et al., 2024**), and patient-related factors. Addressing these issues is critical to improving outcomes for individuals with traumatic dental injuries (**Taylor et al., 2021**).

a. Complexity of Dental Trauma Cases

Dental trauma often involves multiple tissues, including enamel, dentin, pulp, and periodontal structures. Each layer requires precise and sometimes differing interventions, which can make diagnosis and treatment planning difficult. For instance, crown fractures may obscure more serious injuries like root fractures, leading to delayed or improper treatment. The outcomes of such cases depend heavily on the practitioner's ability to assess all injury aspects promptly (**Arbuckle et al., 2023**). In pediatric cases, primary dentition injuries can be particularly challenging as they may affect the development of permanent teeth, requiring specialized management strategies (**Day et al., 2020**).

b. Gaps in Knowledge and Training

Many general practitioners and non-dental healthcare providers lack adequate training to manage dental trauma effectively. Studies indicate significant knowledge gaps among medical doctors and even senior dental students in recognizing and treating dental injuries. This deficiency often results in suboptimal early interventions, which can lead to worsened outcomes for patients (**Yeng et al., 2020**). Furthermore, dentists in public health systems report

challenges in maintaining updated theoretical knowledge and practical skills due to limited access to specialized training programs (Cvijic et al., 2024).

c. Variability in Treatment Guidelines and Practices

Treatment guidelines for dental trauma are often underutilized due to inconsistencies in their application or lack of awareness among practitioners. For instance, while the International Association of Dental Traumatology (IADT) provides comprehensive guidelines, adherence varies significantly, especially in general practice settings (Levin et al., 2020). This variability can lead to inconsistent treatment outcomes, particularly for complex cases such as avulsed teeth or luxation injuries (Fouad et al., 2020). There is a pressing need to improve public and professional education on dental trauma first aid. Initiatives targeting schools, sports organizations, and community health programs can empower teachers, parents, and caregivers to respond effectively to dental injuries (Tzimpoulas et al., 2020).

d. Patient-Related Factors

Patients' behaviors and circumstances significantly affect the management and outcomes of dental trauma cases. Late presentation, lack of first-aid knowledge, and behavioral challenges, particularly in pediatric patients, are key issues that hinder effective treatment. Delayed presentation for care is a common barrier to successful dental trauma management. Studies have found that patients, particularly in rural or underserved regions, frequently seek care at intermediary facilities, which prolongs the time to definitive treatment. For example, pediatric injury cases in Tanzania revealed an average delay of over 8 hours when initial care was sought at non-specialist facilities, leading to poorer outcomes and higher mortality rates (Keating et al., 2022). Similar patterns are observed in dental trauma, where delayed replantation of avulsed teeth drastically reduces survival rates (Fouad et al., 2020).

Public knowledge of appropriate first-aid measures for dental injuries, such as avulsion, is alarmingly low. A systematic review reported that fewer than 50% of teachers knew about replanting avulsed teeth, and only 17% were aware that replantation should occur within 30 minutes (Tewari et al., 2020). Moreover, many patients and caregivers lack the necessary information to preserve avulsed teeth in an appropriate medium, further jeopardizing treatment success. Ultimately, preventive measures for dental trauma are underemphasized despite their importance. Risk factors such as sports participation or unsafe environments at home and school are often overlooked. General practitioners are in a key position to educate families on preventive strategies, such as wearing mouthguards during sports. However, this requires systematic efforts and targeted programs (Kalsi & Burns, 2023).

e. Multidisciplinary Collaboration

Effective dental trauma management often necessitates collaboration among various specialists, including endodontists, oral surgeons, pediatric dentists, and other healthcare professionals (Diluzza, 2024). However, ensuring timely and coordinated care is particularly challenging in rural or resource-limited areas where access to specialized services is often constrained. For instance, pediatric dental trauma may require the involvement of pediatric dentists for behavioral management, oral surgeons for fractures, and endodontists for pulp injuries. A study by Steeves et al. (2023) highlights that emergency department physicians, who are often first responders to dental trauma cases in both urban and rural areas, require better training and collaboration pathways to ensure timely referral to specialists (Steeves et al., 2023).

Rural regions face unique barriers, including geographic isolation, limited availability of specialized dental services, and high staff turnover. These factors exacerbate the difficulty of coordinating multidisciplinary care. Santomauro et al. (2024) noted that telehealth infrastructure can be pivotal in providing specialist consultations to rural clinicians, alleviating professional isolation and improving trauma care quality (Santomauro et al., 2024). Similarly, tele-dentistry has been recognized as an effective tool for enhancing collaboration between rural general practitioners and urban specialists, ensuring continuity of care and expertise sharing (Stuart et al., 2017). Integrating telehealth systems allows real-time consultations and specialist guidance for rural practitioners. This approach has proven effective in improving care coordination and decision-making in emergency scenarios (Ohl et al., 2013).

Providing non-dental healthcare providers, such as emergency physicians and nurses, with training in dental trauma management can bridge initial care gaps. Enhanced awareness of dental trauma pathways improves the referral process and patient outcomes (Beech et al., 2015). Establishing regional networks for dental trauma care can also ensure better communication and coordination among specialists. Barnett et al. (2017) emphasized that fostering relationships between general and specialized dental practitioners improves service delivery, particularly in underserved areas (Barnett et al., 2017).

Conclusion

Advances in diagnostic tools such as CBCT, the integration of bioceramic materials in endodontic, and the adoption of AI and 3D printing technologies have significantly enhanced the precision, efficiency, and outcomes of dental trauma care. These innovations have improved the ability to diagnose complex injuries, preserve tooth vitality, and restore aesthetics and function. However, challenges persist in the form of delayed care, gaps in knowledge and

training among healthcare providers, and variability in the application of evidence-based guidelines. Addressing these barriers requires a multifaceted approach that includes enhanced education for healthcare professionals, public awareness campaigns, and the promotion of interdisciplinary collaboration. Ultimately, the review emphasizes the importance of a proactive, patient-centered approach to dental trauma management. By prioritizing education, prevention, and innovation, healthcare systems can mitigate the long-term impacts of traumatic dental injuries and improve quality of life for affected individuals.

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