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Integrated Public Health and Nursing Approaches in the Prevention and Management of Dental Trauma in Children: A Multidisciplinary Perspective

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Abstract

Background: Traumatic Dental Injuries (TDIs) are a highly prevalent global public health issue in children, with lifetime rates of 20-30%. These injuries, often affecting the maxillary incisors, can lead to severe complications like pulp necrosis and root resorption, causing lasting functional, aesthetic, and psychosocial consequences that impair a child's quality of life.

Aim: This article aims to synthesize a comprehensive, multidisciplinary approach to the prevention and management of pediatric dental trauma, integrating perspectives from dentistry, nursing, and public health to improve clinical outcomes and reduce health disparities.

Methods: The review examines the etiology, risk factors, and classification of TDIs using International Association of Dental Traumatology (IADT) guidelines. It evaluates diagnostic methods, including traditional clinical exams and advanced perfusion-based technologies like laser Doppler flowmetry and pulse oximetry. Treatment strategies for primary and permanent teeth are analyzed, alongside preventive public health interventions and the psychological impact of trauma.

Results: TDIs are influenced by age-specific behaviors and socioeconomic factors, with significant disparities in care access. Accurate diagnosis is enhanced by perfusion-based vitality tests, which are more reliable than traditional methods in children. Management is staged and biology-focused, prioritizing pulp preservation in young permanent teeth. Effective prevention requires educational programs for caregivers and school personnel, policy mandates for mouthguards in sports, and digital health tools to guide first responders.

Conclusion: A coordinated, multidisciplinary strategy that bridges clinical dentistry, nursing, and public health is essential to mitigate the incidence and long-term sequelae of pediatric dental trauma. This integrated approach ensures timely intervention, equitable access to care, and improved psychosocial and functional outcomes for children worldwide.

Keywords: Pediatric Dental Trauma, Traumatic Dental Injuries (TDI), Multidisciplinary Care, Public Health Prevention, Pulp Vitality Testing, Avulsion Management.

Introduction

Pediatric traumatic dental injuries (TDIs) constitute a widespread challenge at the nexus of clinical dentistry, nursing practice, and public health, with multicountry epidemiologic estimates indicating lifetime prevalence rates of approximately 20% to 30% among children and adolescents worldwide [1,2]. Biomechanical and developmental factors explain much of this burden: the maxillary central incisors, positioned anteriorly and often supported by incompletely developed roots during childhood, are disproportionately affected because immature periodontal and alveolar structures offer reduced resistance to impact forces, predisposing these teeth to enamel–dentin fractures, luxation injuries, and complete avulsion [3,4]. Age-stratified risk further clarifies vulnerability patterns. In preschool-aged children (1–3 years), underdeveloped motor coordination and a high incidence of household falls are dominant drivers of injury, whereas in school-aged populations, sports participation, playground activities, and road-user incidents—including bicycle and e-scooter crashes—assume increasing etiologic importance and diversify the clinical spectrum of TDI mechanisms encountered in primary and emergency care settings [5,6]. These distinct trajectories

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underscore the need for setting-specific prevention, anticipatory guidance, and rapid access pathways to dental and medical evaluation when injuries occur [2,5]. The clinical and socioeconomic ramifications of TDI are substantial and frequently protracted. Beyond the immediate structural insult, complications such as pulp necrosis (PN), inflammatory and replacement root resorption, and disturbances in occlusal development can culminate in lasting functional compromise, aesthetic dissatisfaction, and psychosocial distress that impairs oral health–related quality of life (OHRQoL) for both children and their families [7]. The distribution of disease is also marked by pronounced inequities. Evidence from low- and middle-income countries (LMICs) and conflict-affected regions demonstrates higher TDI prevalence, later presentation, and greater complication rates—patterns often attributable to constrained access to preventive services, limited availability of urgent dental care, and gaps in follow-up continuity [1,8]. Within high-income settings, socioeconomic gradients persist: children in marginalized communities not only experience higher exposure to environmental hazards but also face logistical barriers that erode adherence to review appointments, increasing the likelihood of missed diagnoses of PN, delayed management of resorption, and avoidable tooth loss over time [9]. These disparities highlight the imperative for integrated public health strategies—spanning injury surveillance, school- and community-based prevention, caregiver education, and interprofessional referral networks—to close outcome gaps and improve long-term dentoalveolar development [1,7,8].

Standardization of diagnosis and management has advanced with the promulgation of the International Association of Dental Traumatology (IADT) guidelines, which offer a taxonomy for injury classification and evidence-based protocols for acute care, splinting, endodontic decision-making, and follow-up intervals tailored to injury type and root maturity [10]. Yet, notable diagnostic challenges endure in the early post-trauma window. Traditional sensibility tests—thermal stimuli and electric pulp testing—are limited in pediatric populations and shortly after injury because transient neural dysfunction and post-impact ischemia can yield false-negative results, confounding the differentiation between reversible ischemic changes and evolving irreversible pulp necrosis [11]. In this context, emerging physiologic vitality measures that interrogate real-time pulpal perfusion have become increasingly valuable. Laser Doppler flowmetry (LDF) and pulse oximetry (PO) provide noninvasive assessments of microvascular blood flow and oxygen saturation within the pulp, respectively, enhancing diagnostic confidence during the critical period when treatment choices—such as conservative observation versus early endodontic intervention—carry major prognostic implications for root development and long-term tooth retention [11,12]. Ultrasound Doppler flowmetry (UDF) has also shown promise in detecting intrapulpal hemodynamics without the drawbacks of traditional sensibility testing, expanding the toolkit for child-friendly, repeatable monitoring during follow-up [12]. Incorporating these technologies into guideline-based care pathways allows clinicians to balance overtreatment risks against the dangers of therapeutic delay, while interprofessional collaboration with nursing and primary care teams supports timely reassessment, pain control, and caregiver adherence to splint maintenance, diet modification, and oral hygiene instructions [10–12]. Collectively, this integrated approach—grounded in epidemiologic insight, equity-focused public health interventions, and perfusion-based diagnostics—aims to mitigate the lifelong functional and psychosocial sequelae of TDI and to improve outcomes across diverse pediatric populations [1–12].

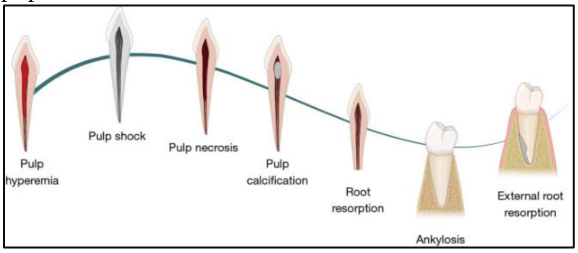

Figure-1: Main complications of pediatric dental trauma.

Clinical Classification and Risk Factors

The clinical classification of pediatric traumatic dental injuries (TDIs) is governed by the standardized criteria established by the International Association of Dental Traumatology (IADT), which serves as the global benchmark for diagnosis, prognosis, and treatment planning [14]. This system organizes dental trauma into hierarchical categories—minor, moderate, and severe—reflecting the extent of tissue involvement, displacement, and pulpal compromise. Minor injuries such as enamel fractures or concussions are confined to the outer enamel surface or periodontal ligament strain, typically producing minimal discomfort and requiring conservative management. Moderate injuries include crown fractures without pulpal exposure and subluxation injuries, which exhibit mobility or sensitivity but retain pulp vitality and structural stability. Severe injuries encompass a spectrum of conditions—crown fractures with pulpal involvement, root and crown–root fractures, extrusive, lateral, or intrusive luxations, and avulsions—all of which carry heightened risks of necrosis, infection, or tooth loss, often necessitating endodontic, surgical, or prosthetic intervention. The most complex form, alveolar bone fracture, may involve concomitant soft tissue damage and displacement of multiple teeth, requiring multidisciplinary coordination among dental surgeons, pediatric nurses, and radiologists for comprehensive care. The classification system thus provides a structured clinical language that facilitates uniform reporting, evidence-based management, and comparative research across populations and healthcare settings [14]. From an etiological perspective, pediatric dental trauma arises from an interplay of biological, behavioral, and environmental determinants that together shape susceptibility and severity. Biological predispositions include the anterior prominence of maxillary central incisors combined with underdeveloped alveolar bone, which confers mechanical vulnerability during facial impact [15]. Developmental and neurological conditions such as autism spectrum disorder (ASD) and cerebral palsy (CP) further amplify risk by impairing motor coordination and postural control, making accidental falls more frequent and potentially more damaging [16,17]. Similarly, obesity—defined as a body mass index (BMI) $\geq$25 kg/m^2—has emerged as a biomechanical risk factor; excess body weight increases both the likelihood and impact force of falls, intensifying dental and alveolar injury severity [18]. Age-related physiology also plays a critical role, as preschool-aged children (1–3 years) exhibit immature reflex responses and limited protective behaviors, leading to high fall incidence and greater involvement of primary teeth [18].

The behavioral and environmental context surrounding the child exerts an equally important influence. Inadequate parental supervision, especially in home settings with unsafe surfaces or unprotected furniture edges, remains a leading contributor to early childhood dental trauma [19]. In older children, sports and recreational activities are a dominant source of injuries, particularly when protective devices such as mouthguards are neglected despite established preventive recommendations [20]. Epidemiological data highlight that athletes participating in contact sports or high-speed recreational activities face a significantly higher risk of luxation and crown fractures, with evidence showing that electric scooter use results in more severe injury profiles—specifically, higher rates of crown fractures and avulsions (45%) compared with traditional bicycle-related trauma (28%) [21]. This shift reflects modern lifestyle changes, urban mobility trends, and the increasing popularity of micro-mobility devices among school-aged children, necessitating updated injury prevention frameworks in community health and school-based education programs. Socioeconomic status (SES) exerts a profound effect on trauma outcomes. Children from low-income families often encounter delayed access to emergency dental care due to financial, geographic, or systemic barriers. Prolonged treatment latency correlates with increased rates of pulp necrosis, infection, and unfavorable long-term prognosis, especially in avulsion and luxation injuries that require immediate intervention for optimal tooth survival [21]. Educational disparities compound this issue, as caregivers with limited oral health literacy may underestimate the urgency of prompt dental evaluation after trauma. In such cases, school nurses and community health workers play a critical role in early identification and referral, reinforcing the importance of interprofessional collaboration between dental and public health sectors to bridge care gaps.

Cultural practices and community infrastructure further shape trauma epidemiology. In regions with limited playground safety standards, poorly maintained sports fields, or absence of traffic regulation for children's cycling, injury prevalence and severity increase disproportionately [19,20]. Conversely, in structured environments with health-promotive policies—such as mandatory helmet use, mouthguard distribution, and early childhood safety education—the frequency and intensity of TDI decline markedly. The nursing workforce is instrumental in implementing these preventive measures within schools and community health programs by delivering education on accident prevention, first aid for avulsed or displaced teeth, and timely referral pathways to dental specialists. Ultimately, the risk landscape for pediatric dental trauma is multifactorial, extending beyond individual biology to encompass social, behavioral, and infrastructural determinants. Addressing this complexity requires a multidisciplinary approach uniting dentists, pediatricians, nurses, radiologists, and public health professionals in surveillance, prevention, and early intervention. The IADT classification provides a universal framework for consistent diagnosis and documentation, while the identification of modifiable risk factors underpins targeted preventive strategies. By integrating biological insights, behavioral education, and systemic policy reforms, health systems can mitigate the incidence and severity of dental trauma, promoting equitable and sustainable oral health outcomes in pediatric populations [14–21].

Main complications

Traumatic dental injuries (TDI) in children precipitate a cascade of complications that may involve the dental pulp, periodontal ligament, and root structures, with clinical and radiographic features evolving over weeks to years. The earliest pulp response is often pulp hyperemia, a transient vasodilatory state marked by vascular congestion within the pulp chamber that reflects an acute neurovascular reaction to mechanical insult rather than established tissue necrosis [22]. Clinically, children may report brief, stimulus-dependent sensitivity, and the tooth typically remains responsive to sensibility testing; because these changes are physiologic and potentially reversible, management is conservative with analgesia and occlusal protection when indicated. If the initial inflammatory surge is pronounced, a phase of pulp shock can follow—functional neural inhibition that renders sensibility tests falsely negative during the first days after trauma, particularly in immature teeth whose plexus of Raschkow remains developmentally labile [23]. In this interval, reliance on a single test risks misclassification; dynamic observation using serial examinations and adjunctive perfusion-based vitality assessments is therefore recommended to differentiate transient neural dysfunction from evolving irreversible damage [23]. As healing proceeds, a subset of traumatized teeth undergo pulp canal obliteration (PCO), a form of pulpal calcific metamorphosis characterized by accelerated deposition of hard tissue within the canal space. Pediatric series estimate PCO in approximately 4.9% of traumatized primary teeth, with a significant association observed after subluxation injuries, likely reflecting neurovascular dysregulation that stimulates odontoblastic activity and intrapulpal mineralization [24]. Although many teeth with PCO remain clinically asymptomatic, the progressive narrowing or complete obliteration of the canal complicates any future endodontic access, and radiographic opacity can obscure coexisting pathology, masking underlying pulp necrosis (PN) or low-grade infection [24]. The most consequential pulp complication, PN, signifies complete loss of vitality with microbial colonization of the canal system. In practice, PN is inferred from a constellation of findings: persistent non-responsiveness to cold and electric pulp testing beyond the expected window for neural recovery, crown discoloration that may progress from yellowish to greyish-black, and delayed signs of periapical inflammation such as tenderness, swelling, or a draining sinus tract [25]. Risk is injury- and dentition-specific: in primary teeth that are subluxated, a 1-year PN risk of 8.3% has been reported (95% CI: 4.8–11.8%), underscoring the need for structured follow-up to intercept early periapical disease [26]. In the permanent dentition, injuries compounded by alveolar process fractures carry substantially higher long-term risk, with PN reported in 56% of cases over 10 years (95% CI: 48.1–63.9%), a trajectory that frequently necessitates root canal therapy or, in advanced infection, extraction [27].

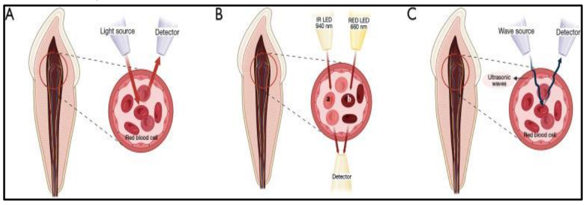

Figure-2: Overview of three distinct techniques used to detect blood flow patterns in dental pulp.

Root complications after TDI cluster broadly into resorptive disorders and fractures. Inflammatory external root resorption (IER) arises when post-traumatic infection or sterile inflammation disrupts the cementum–periodontal ligament (PDL) barrier, activating clastic cells that remove dentin and cementum. Radiographically, IER exhibits irregular, "moth-eaten" lacunae along the root surface with contiguous periapical radiolucency, often accompanied by tenderness to percussion and increased mobility when the lesion is extensive [28]. Unlike IER, replacement resorption (RR)—also termed ankylosis—reflects direct osseous substitution of the root following damage to or loss of PDL cells; it is particularly prevalent in teeth with open apices at the time of injury or when treatment is delayed, because the denuded root surface becomes colonized by bone-forming cells, integrating the root into alveolar bone with a characteristic metallic percussion note and infraocclusion in growing children [28]. A retrospective analysis by Yamashita et al. (2017) quantified the incidence of RR at 8% following luxation injuries and identified salient risk amplifiers on multivariable modeling: male sex (P=0.0392; OR=2.79), avulsion as the index trauma (P=0.0009; OR=12.27), and >16-day delay from trauma to initiation of endodontic treatment (P=0.0450; OR=7.53), each independently associated with a heightened likelihood of adverse post-trauma sequelae including RR [29]. These data emphasize the twin imperatives of prompt revascularization or root canal protocols and vigilant longitudinal surveillance. Periodontal complications map onto the spectrum of PDL injury. Concussion denotes PDL contusion with intact tooth position; children typically present with occlusal tenderness, minimal mobility, and normal radiographs, and the condition resolves with rest and soft-diet measures as the PDL recovers [30]. Subluxation represents a step-up in severity, characterized by increased mobility, gingival sulcus bleeding, and widened PDL space radiographically, but without displacement of the tooth from its socket; while many cases heal uneventfully, subluxation is a recognized precursor for PCO and a nontrivial risk factor for PN in the primary dentition, warranting splinting when mobility threatens function and scheduled vitality checks thereafter [24,30]. More severe luxation injuries—extrusive, lateral, and intrusive—and avulsion impose complex biomechanical and microbiologic burdens on the PDL and cementum, setting the stage for IER or RR if decontamination, repositioning, and stabilization are not executed swiftly and in line with guideline-based protocols [28–30].

In the primary dentition, the ramifications of TDI extend beyond the injured tooth to the developing permanent successor, either indirectly through inflammatory mediators emanating from an infected primary root or directly via mechanical insult to the tooth germ because of the intimate anatomical relationship between primary incisor apices and permanent incisor follicles [31]. Sequelae in permanent successors encompass a broad range: enamel hypoplasia or hypomineralization, crown or root malformation, dilaceration, eruption disturbances, and aesthetic defects that can carry psychosocial consequences. Case–control studies report a significantly elevated risk of sequelae in permanent successors (SPS) following trauma to primary teeth, with odds ratios indicating materially higher odds of developmental disturbances compared with non-traumatized controls (e.g., OR=5.388), findings that persist after adjustment for age and injury type [32]. These observations mandate structured, age-appropriate recall schedules with periodic periapical radiography or low-dose cone-beam CT when indicated, enabling early identification of aberrant development and timely interceptive care [31,32]. The clinical course across these complication domains is shaped by injury severity, root maturity at the time of trauma, timeliness of care, and adherence to follow-up. Immature permanent teeth retain regenerative advantages—apical papilla stem cells and robust vascular potential—that can support continued root development if revascularization or vital pulp therapies are instituted before infection is established; conversely, mature teeth with closed apices are more reliant on conventional endodontics when PN ensues [25,27]. Adjunctive diagnostics that evaluate pulpal perfusion—including laser Doppler flowmetry and pulse oximetry—are particularly useful in the ambiguous early period to avoid premature declarations of PN and unnecessary endodontic treatment while still recognizing signs that warrant intervention, thereby reducing the risk of IER by limiting persistent intraradicular infection [23,25]. For luxation and avulsion injuries, meticulous attention to splinting biomechanics, antiseptic protocols, and systemic factors such as the child's nutritional status and oral hygiene habits can modulate healing trajectories and mitigate PDL-mediated complications [28–30].

From a systems perspective, the burden of TDI complications underscores the importance of rapid-access pathways and interprofessional coordination. School nurses and primary care teams are pivotal in early recognition, initial advice—such as immediate replantation of avulsed permanent incisors when feasible—and expedited referral. Dental teams must implement guideline-based recall intervals to detect delayed PN, monitor for PCO progression, and identify early radiographic signs of IER or RR so that endodontic or surgical interventions are not deferred beyond windows of optimal efficacy [24–29]. Equally, caregivers should receive clear, developmentally appropriate education on splint care, diet modification, and signs of infection to improve adherence and outcomes. In aggregate, the main complications of pediatric TDI—spanning pulpal hyperemia and shock through PCO and PN, and from IER and RR to PDL injuries with periodontal sequelae—are largely predictable consequences of the initial biomechanical insult and subsequent biologic responses. With vigilant surveillance, judicious use of perfusion-based diagnostics, and timely evidence-based intervention, clinicians can substantially attenuate the long-term functional and developmental impact of these injuries on the growing child [22–32].

Clinical diagnosis

Accurate diagnosis of traumatic dental injuries (TDI) in children requires a structured synthesis of clinical findings and judicious imaging, tailored to the child's stage of dental development and the injury mechanism. The diagnostic process begins at the chairside, where meticulous history-taking establishes the timing of the event, the vector and magnitude of force, and any first-aid measures undertaken before presentation, all of which influence pulpal and periodontal prognoses and the urgency of intervention [33]. Clinical examination proceeds extraorally and intraorally, with careful inspection of the lips, cheeks, and perioral tissues for abrasions, lacerations, hematomas, and embedded foreign bodies that may seed infection or indicate occult fractures. Intraorally, the clinician documents tooth integrity, enamel–dentin involvement, cusp fractures, and crown–root violations; assesses displacement patterns consistent with concussion, subluxation, and extrusive, lateral, or intrusive luxation; and evaluates pathologic mobility as a marker of periodontal ligament (PDL) injury. Percussion and palpation disclose tenderness suggestive of alveolar involvement, while greyish-black discoloration, sinus tracts, or swelling heighten concern for pulpal necrosis (PN) or apical pathology in delayed presentations [33]. Standardized photographic documentation and tooth vitality testing—interpreted cautiously in the acute phase—support baseline recording and longitudinal comparison [33]. Isolated clinical assessment, however, can miss clinically silent but consequential pathology. In a cohort of 674 preschool children, radiographic surveillance uncovered pulp canal obliteration (PCO) and root fractures in 2.5% of cases that were clinically asymptomatic, whereas 40.8% of injuries exhibited clinical signs without corroborative radiographic changes, underscoring the imperfect sensitivity and specificity of periapical radiographs when used as a sole arbiter of pathology [34]. These discordances reflect both the temporal evolution of TDI sequelae—many of which lag behind symptoms—and the technical constraints of two-dimensional imaging, including projection errors and an inability to visualize buccolingual displacement or early resorptive lacunae [34]. Because children are especially susceptible to ionizing radiation, the indication for every image must be justified and optimized under the "as low as reasonably achievable" (ALARA) principle, with collimation, high-speed sensors, and exposure parameter adjustment to minimize dose while preserving diagnostic yield [35]. For primary tooth trauma, conventional periapical radiography remains the first-line modality; routine cone-beam computed tomography (CBCT) is discouraged due to radiation burden and the typically self-limiting natural history of primary tooth injuries that nonetheless require close clinical follow-up [36].

When injury patterns are complex—particularly in the permanent dentition—cross-sectional imaging can decisively alter diagnosis and management. Low-dose CBCT offers true three-dimensional reconstruction with superior depiction of root fractures, alveolar process disruption, and early external or replacement resorption that are often occult on periapicals, thereby refining both prognosis and treatment planning [37]. In a retrospective analysis of 190 pediatric patients with maxillary anterior trauma, low-dose CBCT significantly outperformed periapical radiography across these endpoints, with direct implications for surgical repositioning, splint design, and endodontic timing [37]. A separate study of 35 traumatized maxillary anterior teeth reported markedly higher sensitivity and accuracy for CBCT compared with conventional radiographs—99% and 91% versus 84% and 70%, respectively—supporting its role as a complementary modality in complex permanent-tooth trauma where benefits outweigh radiation risks [38]. Even with these advantages, CBCT should be reserved for scenarios in which its added information will change management, and protocols should employ pediatric field of view and low-dose settings in strict adherence to ALARA [35–38].

Clinical examination

Beyond structural appraisal, a nuanced occlusal examination identifies functional interferences, traumatic occlusion, and premature contacts created by displacement, which, if unaddressed, perpetuate PDL inflammation and compromise splint stability. Soft-tissue exploration—after anesthesia and antisepsis—may reveal tooth fragments that require removal to prevent granuloma formation and facilitate primary closure of lacerations. Baseline periodontal charting, including probing depths around displaced teeth, can disclose alveolar socket fractures, while gentle mobility grading helps stratify splinting needs and duration. Sensibility testing during the acute window must be interpreted with caution because transient neural dysfunction and microcirculatory changes can yield false-negative results; serial examinations contextualize early findings within the trajectory of recovery or deterioration [33,34]. Documentation of pain descriptors, analgesic response, and functional limitations (bite, speech) provides additional outcome measures for follow-up comparison, particularly in children whose subjective reporting may be influenced by anxiety or communication barriers [33,39].

Pulp vitality testing

Determining true pulp status after trauma is central to prognosis yet remains challenging in pediatric care. Traditional sensibility tests—cold and electric pulp testing (EPT)—interrogate neural response rather than perfusion and are therefore vulnerable to both biologic and behavioral confounders in children. Anxiety and fear can lead to test refusal or inconsistent responses, while immature permanent teeth with open apices lack fully formed neural pathways and apical constriction, diminishing EPT reliability and increasing the rate of false negatives during the early post-trauma period of neurapraxia [39,40]. Consequently, exclusive reliance on sensibility tests risks overtreatment (unnecessary endodontics) or undertreatment (missed PN). These limitations have accelerated clinical adoption of perfusion-based technologies that directly measure pulpal blood flow (PBF) as a surrogate for vitality, thereby offering objective, noninvasive endpoints for decision-making in the weeks following injury [40,41]. Laser Doppler flowmetry (LDF) quantifies movement of erythrocytes within the microvasculature by detecting frequency shifts in backscattered monochromatic light, generating perfusion units that correlate with blood flow velocity in real time [41]. In pediatric cohorts, LDF has consistently demonstrated diagnostic value. Belcheva et al. reported significantly higher LDF signals in traumatized but vital teeth compared with contralateral controls in an 88 case split-mouth design, facilitating early confirmation of perfusion recovery when sensibility tests remained negative [42]. Longitudinally, Ersahan et al. showed that LDF tracked revascularization in extrusively luxated immature incisors, with increases beyond approximately 4.5 perfusion units over six months aligning with favorable clinical courses and continued root development [43]. Importantly, Roeykens et al. demonstrated that LDF could reclassify 43% of teeth initially labeled necrotic on conventional testing to vital status, thereby avoiding premature endodontic intervention and distinguishing transient apical breakdown from true necrosis during the critical observation window [44]. Collectively, these data support LDF as an adjunct that enhances specificity for vitality in children when neural-based tests are equivocal [41–44].

Pulse oximetry (PO) adapts familiar medical technology to dentistry by estimating intrapulpal oxygen saturation (SpO_2) from the differential absorption of red and infrared light, calculating the oxyhemoglobin to deoxyhemoglobin ratio noninvasively at the tooth surface [50]. Its appeal in pediatrics lies in its objectivity and child-friendly interface. In a large cross-sectional study of 329 immature incisors, Bargrizan et al. documented higher physiologic SpO_2 baselines in open-apex teeth, consistent with robust vascular potential for healing after TDI and providing age- and development-sensitive reference values for interpretation [45]. Building on these normative data, Caldeira et al. proposed clinically actionable thresholds in 59 luxated teeth: $SpO_2 \leq 77\%$ predicted PN, whereas values $\geq 90\%$ signaled likely recovery, enabling risk-stratified follow-up and timely intervention [46]. More recently, Bux et al. reported 100% diagnostic accuracy for PO across 40 traumatized teeth when compared against definitive clinical outcomes, outperforming traditional tests in objectivity and reproducibility and reinforcing PO's role as a frontline vitality tool in pediatric trauma protocols [47,50]. Ultrasound Doppler flowmetry (UDF) employs high-frequency sound waves to capture pulpal vascular dynamics, offering real-time assessment without optical access limitations through thick enamel or composite restorations [51]. In a comparative analysis of 246 traumatized teeth, Ahn et al. observed significantly higher one-year pulp survival with UDF-guided management than with EPT-based pathways (90% vs. 74%), suggesting that perfusion-driven decision-making can measurably improve outcomes after TDI [48]. Complementary physiologic benchmarks were provided by Cho et al., who defined normative PBF velocity in healthy anterior teeth at approximately 0.5–0.6 cm/s, furnishing a practical reference range for post-trauma interpretation and longitudinal monitoring in children [49,51]. Integration of UDF with LDF or PO allows triangulation of perfusion status where single-modality readings are ambiguous, especially in mixed dentition with variable enamel thickness and root maturity [41,48–51].

Emerging modalities further expand the diagnostic armamentarium. Transmitted-light plethysmography has demonstrated higher baseline PBF in mature versus immature teeth and the capacity to detect reversible perfusion fluctuations during thermal provocation, opening avenues for stress-testing the microcirculation without nociceptive stimulation in anxious children [52,53]. Magnetic resonance imaging (MRI) offers radiation-free structural and functional insights; early studies report up to 90% sensitivity for detecting incipient necrosis and superior visualization of early degenerative pulpal changes compared with radiography, a particularly attractive proposition for pediatric follow-up when CBCT is unwarranted or contraindicated [54,55]. Although currently limited by cost, access, and the need for motion-tolerant protocols, these technologies underscore a broader shift toward physiology-first diagnostics that align with pediatric needs and ALARA principles [35,52–55]. Across the diagnostic pathway, calibration of operators, standardized testing conditions, and consistent recall intervals are essential to interpret trajectories rather than isolated snapshots. In practice, clinicians should pair focused clinical examination with age-appropriate imaging selection and adopt perfusion-based vitality tools during the early post-injury period when sensibility tests are least reliable. This integrated approach mitigates the risks of both overtreatment and missed pathology, supports timely revascularization or endodontic decisions, and respects the unique radiobiologic vulnerability of children—cornerstones of high-quality care in pediatric dental trauma [33–36,40–47,50–55].

Treatment methods

Effective management of traumatic dental injuries (TDI) in children hinges on aligning diagnostic and therapeutic choices with the severity of tissue damage and the developmental stage of the involved teeth. Clinical practitioners should approach every case in three coordinated phases—emergency management, transitional therapy, and definitive restoration—while keeping the overarching objective of vital-pulp preservation to enable continued root development whenever biologically feasible. Emergency care focuses on hemostasis, pain control, contamination reduction, and stabilization. This includes atraumatic soft-tissue debridement, irrigation of lacerations, tetanus status review where indicated, and prompt repositioning and splinting of displaced teeth when required, all while instituting a structured baseline record of mobility, percussion sensitivity, occlusion, and sensibility testing that will anchor subsequent decision-making. Transitional therapy addresses the short- to mid-term healing trajectory—typically the first 4 to 12 weeks—when the risks of pulpal necrosis, inflammatory external root resorption, and periodontal ligament (PDL) breakdown are at their peak. In this window, clinicians prioritize reversible, biologically conservative interventions such as partial pulpotomy for exposed vital pulps in immature teeth, flexible splinting to protect the PDL, and antimicrobial or remineralizing adjuncts as indicated. Definitive restoration is planned only after the trajectory of pulpal and periodontal healing becomes clear, integrating adhesive rehabilitation, endodontic therapy if vitality is irretrievably lost, and, in selected cases, regenerative or surgical procedures designed to re-establish form and function with the least biological cost. Across all phases, careful counseling of families and age-appropriate behavioral guidance are critical for adherence, as is close follow-up with vitality and radiographic reassessment to detect early deviations from expected healing. In essence, treatment planning for pediatric TDI is not a single decision point but a sequence of adaptive choices that privilege pulp preservation, protect the PDL, and respect the unique vulnerability and regenerative potential of the growing dentition.

Primary tooth management

The guiding principle in the primary dentition is to preserve comfort and function while minimizing the risk of harm to the developing permanent successors that lie in intimate anatomical relation to primary incisors. Because primary teeth have open apices and thin alveolar support, many injuries can be managed conservatively once life-threatening conditions are excluded and soft tissues are stabilized. Intrusive luxation is a prime example where “watchful waiting” is generally preferred. A retrospective cohort of 238 intruded primary teeth demonstrated that spontaneous re-eruption occurred in 68% within six months, supporting observation instead of surgical repositioning in the absence of complications such as infection, occlusal interference, or soft-tissue entrapment [56]. When displacement threatens function or occlusion in lateral luxation or when fractures destabilize the tooth, flexible splinting for approximately four weeks protects the PDL while tissues recover, with the evidence base supporting this timeframe for stability without provoking ankylosis [57,58]. In sharp contrast to the permanent dentition, replantation of avulsed primary teeth is contraindicated because of the high risk of damaging the permanent tooth bud and provoking sequelae such as enamel discoloration, hypoplasia, or crown/root malformations in the successor [59,60]. Instead, management emphasizes prompt wound care, pain control, age-appropriate space maintenance if indicated, and longitudinal clinical and radiographic surveillance of the underlying permanent germ. Parents should receive clear instructions on oral hygiene modifications, soft diet, and red-flag symptoms—including swelling, spontaneous pain, or discoloration—that would mandate earlier reassessment, and practitioners should document each follow-up with attention to signs of infection or pathologic migration that might necessitate extraction to protect the successor. Decisions must also account for the child's cooperation and psychological readiness; minimally invasive, behaviorally sensitive care often yields the best biological and psychosocial outcomes in this age group.

Young permanent tooth management

In immature permanent teeth, the core objective is maintaining or restoring pulp vitality to support apexogenesis and continued root elongation and wall thickening. Where fractures expose the pulp, vital pulp therapy is prioritized: direct pulp capping for pinpoint exposures and partial pulpotomy for wider exposures in well-vascularized coronal pulp. Non-exposed enamel–dentin fractures are managed with immediate dentin sealing and adhesive composite restoration to restore function and prevent bacterial ingress [61]. Clinical outcomes favor this biologically conservative approach. In a retrospective analysis of 99 immature teeth with crown fractures, cervical pulpotomy achieved a 90.4% success rate, underscoring the value of vital pulp therapy in mitigating downstream complications while preserving growth potential [62]. Luxation injuries require tailored responses. Intrusive luxation in young permanent teeth carries a high risk profile; Antipovienė et al. reported a 75% risk of pulp necrosis (PN), and a multicenter series of 230 intruded teeth found similarly high rates of PN (75%), infectious root resorption (25%), and replacement resorption (22%), with root maturity and intrusion depth as dominant risk factors [63,64]. These data justify early endodontic intervention—often vital pulp therapy in immature teeth or timely disinfection protocols in mature roots—paired with orthodontic or surgical extrusion strategies individualized to intrusion severity and the stage of root development. By contrast, partially displaced luxations are typically managed by immediate gentle repositioning, flexible splinting, and structured vitality surveillance, recognizing that a subset will recover without endodontic treatment if perfusion is re-established.

Avulsed permanent teeth represent a true dental emergency in which time-sensitive biological imperatives guide care. Ideal management is immediate replantation at the scene or within 30–60 minutes to maximize PDL cell survival; if immediate replantation is not feasible, storage in Hank's balanced salt solution or, alternatively, in milk is recommended to maintain PDL viability until care is available [65]. After replantation, atraumatic splinting, systemic antibiotics when indicated, and tetanus review are paired with endodontic planning that respects apical status; immature teeth may be candidates for revascularization or apexogenesis if conditions are favorable, whereas mature teeth are typically treated with early canal disinfection to curb inflammatory resorption. Root fractures demand equally nuanced biomechanics. Flexible splinting with stainless steel wire and composite resin is standard, but duration should be tailored to the fracture location and mobility. Evidence suggests that extended splinting intervals (81–110 days) promote hard-tissue union more reliably than shorter periods in selected mid-root fractures, likely by stabilizing micro-motion at the fracture line and allowing mineralized callus to bridge the defect [23,66]. Comfort also matters in pediatrics; a comparative study in 60 children revealed that 0.7-mm wire splints produced superior pain relief compared with 0.4-mm wire without compromising healing, supporting the pragmatic selection of slightly stiffer splints when tolerated [67]. Throughout, scheduled reassessment with perfusion-based vitality tests and targeted imaging under ALARA principles guides the transition from provisional stabilization to definitive restorative and endodontic care.

Pulp therapy and tooth reimplantation

Bioceramic materials have transformed the biological logic of pulp therapy in traumatized teeth by combining biocompatibility, sealing ability, and bioactivity that encourages dentin bridge formation and reduces inflammatory sequelae. Mineral trioxide aggregate (MTA) remains the cornerstone in this class. In complicated crown fractures with pulp exposure, pulpotomy with MTA achieved a 93.6% success rate, outperforming indirect pulp capping, which yielded 76.9% success, likely reflecting MTA's superior sealing and calcium-ion release that stimulates reparative dentinogenesis [68]. In apexification for non-vital immature teeth, MTA has extended median tooth survival to 16.1 years, roughly a 60% improvement over calcium hydroxide protocols whose median survival hovers around 10 years, a difference that may relate to faster apical barrier formation, reduced fracture susceptibility, and fewer long-term dressing changes [69]. When used as a coronal barrier of at least 3 mm thickness in root canal–treated teeth, MTA has been associated with a reduction in post-treatment root fracture risk to 9.8%, a biomechanical advantage attributed to improved stress distribution and microleakage control at the canal orifice [70].

Biodentine offers a complementary bioceramic alternative with favorable handling characteristics; when reinforced with glass fibers, it can increase fracture resistance by approximately 23%, which is clinically relevant in teeth with structurally compromised crowns or thin radicular walls after trauma [71]. Emerging bioactive adjuncts further extend the regenerative promise of conservative care. Aspirin/poly(lactic-co-glycolic acid) (ASP/PLGA) composite membranes have demonstrated anti-inflammatory and pro-mineralization effects in pulp capping models, suggesting a role in blunting early post-traumatic inflammatory cascades while promoting hard tissue formation [10]. Likewise, immunomodulatory peptides such as human β-defensin 4 are being investigated as biologically intelligent signals to enhance pulp regeneration, reflecting a broader translational arc from passive sealing to active tissue engineering [72].

Replantation biology in avulsed teeth is equally amenable to targeted materials and surface biology strategies that aim to salvage the PDL, re-establish attachment, and protect the root against inflammatory and replacement resorption. Protocols increasingly recognize that the root surface is a modifiable interface. In delayed replantation with extra-oral dry time ≥60 minutes, enzymatic decontamination with papain has been shown in preclinical models to reduce resorptive lacunae by 45% at four weeks and to enhance PDL fibroblast colonization versus untreated controls, supporting its use as a deproteinizing step that preserves or restores a hospitable surface for cell repopulation [73]. Regenerative cell-based approaches are also advancing. In a rat avulsion model, transplantation of deciduous dental pulp stem cell (DPSC) aggregates achieved 90% revitalization with demonstrable angiogenesis, substantially outperforming untreated controls that realized only 30% success, an effect likely mediated by paracrine pro-angiogenic and pro-repair signaling as well as direct differentiation [74]. Tissue scaffolds rich in growth factors, such as platelet-rich fibrin (PRF), can potentiate these effects; PRF constructs seeded with bone marrow mesenchymal stem cells (BMMSCs) enhanced proliferation across early time points and facilitated tight cell adhesion, offering a feasible, autologous platform to augment periodontal healing [75]. Translational clinical evidence is beginning to accumulate in a randomized clinical trial involving 50 pediatric patients, low-level laser therapy (LLLT) reduced pain by 41% at seven days and improved PDL healing scores by 29% versus sham, suggesting photobiomodulation can modulate inflammation and stimulate cellular proliferation during the fragile early healing period [76]. For immature apices where infection control and regeneration must be balanced, drug-delivery innovations such as doxycycline-loaded, nitric-oxide-releasing nanogels have shown promise in preclinical work, reducing periapical inflammation by 58% and increasing hard-tissue formation by 34% relative to conventional antibiotic strategies, potentially by combining antimicrobial effects with microvascular support and osteogenic signaling [77]. Together, these results underpin a practical algorithm: when feasible, prioritize immediate replantation within 60 minutes; if delays occur, apply biologically intelligent surface management such as fluoride or enzymatic cleaning; and consider adjunctive regenerative therapies—cellular aggregates, PRF scaffolds, photobiomodulation, or targeted nanotherapeutics—to improve the odds of PDL survival, resist resorption, and foster revascularization [73–77].

The convergence of endodontic biomaterials and replantation biology invites a broader systems-level perspective on pediatric TDI. Optimal outcomes require coordination between emergency services, pediatric dentistry, endodontics, periodontics, and, in complex alveolar injuries, oral and maxillofacial surgery, with nursing teams orchestrating analgesia, splint maintenance education, and recall compliance. Communication with caregivers must be explicit about timelines—for example, the narrow window for replantation, the typical four-week splinting period after many luxations and fractures, and the staged nature of vitality reassessment—so that expectations align with biological realities [57,58,65]. Equally, adherence to radiation stewardship during follow-up is paramount; perfusion-based vitality testing and targeted low-dose imaging can often substitute for routine radiography, honoring pediatric ALARA principles while still safeguarding against missed pathology. Finally, clinicians should remain attentive to psychosocial dimensions—the fear, esthetic concerns, and school disruptions that often accompany pediatric TDI—and should aim for minimally invasive, aesthetically sensitive restorations during the definitive phase to support confidence and normal social participation. In sum, contemporary treatment methods for pediatric TDI are anchored in staged care that privileges vitality, protects the PDL, and uses materials and modalities tailored to developmental biology. In the primary dentition, conservative strategies and avoidance of replantation safeguard the permanent successors while maintaining comfort and function [56–60]. In the immature permanent dentition, vital pulp therapy, timely repositioning and splinting, and decisive management of avulsion and root fractures are orchestrated to preserve growth potential and avert resorptive catastrophes [61–67]. Across scenarios, bioceramic materials such as MTA and Biodentine, together with emerging bioactive adjuncts and regenerative strategies, have expanded the therapeutic toolbox, improving structural integrity, pulp survival, and long-term tooth retention [68–72]. Replantation science now pairs root-surface decontamination with biologically active scaffolds, cellular therapies, and photobiomodulation to bolster PDL healing even when presentation is delayed [73–

77]. Delivering these advances within a multidisciplinary framework ensures that children receive time-critical emergency care, evidence-based transitional therapy, and esthetically durable definitive restorations, all while minimizing radiation exposure and maximizing the chance of lifelong oral health [78].

Psychological impact

Dental trauma in children exerts a profound and multidimensional psychological burden that extends well beyond the acute clinical episode, altering self-perception, social participation, family dynamics, and longer-term health behaviors. At the individual level, the esthetic disruption caused by visible damage to anterior teeth frequently becomes a catalyst for self-consciousness and social withdrawal, particularly during developmental windows when peer acceptance is salient. In a cross-sectional study of 8–13-year-olds with maxillary incisor trauma, Elizabeth et al. reported that fully 80% of children experienced impaired smiling ability, a concrete behavioral manifestation of body image distress and social inhibition; accidental falls were the leading cause, highlighting the ordinary contexts that precipitate an enduring psychosocial impact [79]. The same cohort illuminated gendered differences in care trajectories—34.8% of males experienced treatment delays exceeding one year, whereas 41.7% of females obtained treatment within a year—suggesting that sociocultural norms, parental perceptions of urgency, or differential help-seeking may shape the timeliness of intervention and, by extension, the duration of psychosocial strain [79]. For affected children, the visible consequences of trauma often intersect with critical identity-forming experiences at school, in sports, and in digital social spaces, amplifying the consequences of delayed rehabilitation. Quality-of-life impairments after trauma are not confined to esthetics or pain in isolation; rather, they reflect an aggregate of functional, emotional, and social domains that interact dynamically. Using the German version of the Early Childhood Oral Health Impact Scale (ECOHIS-G), Lembacher et al. found that trauma-induced dental pain nearly doubled the reduction in oral health–related quality of life (OHRQoL) among children aged 0–6 years, underscoring that even very young children experience measurable decrements in well-being when trauma disrupts sleep, eating, and play [7]. The authors further documented significant correlations between the decayed, missing, and filled teeth (dmft) index, plaque accumulation, and child impact scale scores, reinforcing a broader message: trauma-related distress is embedded within a wider oral ecosystem in which caries experience and hygiene practices modulate symptom burden and daily functioning [7]. In this light, dental trauma should be conceptualized as part of a cumulative risk landscape; without targeted support, pain, esthetic concerns, and functional limitations may coalesce into sustained avoidance behaviors and deteriorating self-care.

Psychological sequelae also crystallize in measurable fear and anxiety around dental environments. Kvesić et al. identified parental knowledge gaps, female gender, poor oral hygiene, and recent pain as salient risk factors for dental fear and anxiety (DFA) among traumatized children, explaining 54.5% of the variance on the Child Fear Survey Schedule–Dental Subscale (CFSS-DS) [80]. These findings imply modifiable levers for intervention: caregiver education to correct misconceptions and equip families with coping strategies; pre-visit orientation and desensitization to reduce anticipatory anxiety; and proactive analgesia and minimally invasive techniques to minimize negative conditioning during acute care. Crucially, the data point to the bidirectional nature of DFA: anxiety impairs cooperation and distorts pain perception, which can, in turn, compromise the quality and timeliness of treatment, perpetuating a cycle of avoidance and worsening oral health [80]. Clinicians must therefore embed trauma-informed approaches—clear communication, graduated exposure, and reinforcement of mastery—into both emergency and follow-up care. The psychosocial impact radiates beyond the child to the family system. Procopio et al. demonstrated that dental caries and trauma significantly reduced OHRQoL in children with autism spectrum disorder (ASD), thereby highlighting disproportionate vulnerabilities in special needs populations where sensory sensitivities, communication barriers, and care coordination demands are greater [81]. Families managing neurodevelopmental differences often confront amplified logistical and emotional burdens after trauma, including heightened distress during procedures, challenges in maintaining splint care or dietary modifications, and the need for more frequent follow-up. These stressors can strain caregiver well-being and household routines, with downstream effects on adherence and outcomes. The collective picture from these studies is that pediatric dental trauma erodes multidimensional quality of life through esthetic stigma driving social anxiety, pain and function impairments disrupting daily activities, treatment-related fear conditioning, and caregiver stress that complicates home care [7,79–81]. Addressing this breadth of impact requires clinicians to look beyond the tooth to the child-in-context, integrating psychosocial screening and support into routine trauma pathways.

Preventive strategies and interventions

Prevention and mitigation of the psychosocial and clinical consequences of pediatric trauma demand multilevel responses spanning education, policy, and technology. Educational empowerment is foundational because the first responder to a dental injury is often not a dentist but a caregiver, teacher, coach, or school nurse. Al Sari et al. showed that targeted training for school nurses and physical education teachers significantly improved competence in dental trauma management, with correct responses to avulsion emergencies increasing from baseline to three months post-training [82]. Such competency gains are not merely academic: they translate into earlier and more appropriate first aid (e.g., immediate replantation or proper storage media), which can preserve periodontal ligament viability and shorten the arc from injury to definitive care, thereby reducing both biological complications and the duration of visible disfigurement that fuels psychosocial distress [82]. Complementarily, Sulistyarsi et al. demonstrated that an electronic book intervention shifted primary school teachers' knowledge from poor to good (median scores from 6 to 13, $P<0.05$), illustrating that scalable digital tools can rapidly elevate front-line capacity in resource-constrained settings [83]. These findings argue for institutionalizing trauma education in teacher and coach onboarding, with periodic refreshers to sustain competence. Policy-level initiatives are equally crucial to close the gap between awareness and behavior, particularly in sports. Despite 43% awareness of mouthguards' protective role among sports academy children reported by Pranitha et al., actual use was 0%, with discomfort, perceived lack of necessity, and access barriers cited as reasons [20,14]. This awareness–practice gap underscores that information alone is insufficient; mandates, subsidized distribution, and design innovations that improve comfort and aesthetics are needed to normalize mouthguard use. Schools and clubs can operationalize policies that require mouthguards in contact sports, align vendors to provide low-cost, custom-fit options, and engage parents and athletes in co-design to address comfort objections. In parallel, technology can serve as a just-in-time amplifier. The ToothSOS mobile app, designed for stepwise guidance in trauma scenarios, elicited 91.7% willingness among pediatricians to use it, yet low baseline awareness persists, suggesting that dissemination strategies must be broadened through professional societies, continuing education, and integration into electronic health record toolkits for rapid access [84]. Early evidence that large language models such as ChatGPT can deliver reasonably accurate trauma education (76.7% accuracy for TDI queries) hints at scalable, multilingual avenues for caregiver empowerment; however, systematic validation, safety guardrails, and integration with authoritative guidelines are prerequisites for clinical deployment [85]. An ecosystem approach—curricular training for school personnel, policy mandates for protective gear, and widely publicized digital decision support—creates synergistic reinforcement that can lower incidence, improve first response, and shorten time to definitive care, with tangible benefits for both biological and psychological outcomes [14,20,82–85].

Existing challenges and future directions

Despite advances in protocols, biomaterials, and imaging, several gaps hinder optimal, equitable outcomes in pediatric dental trauma. A central clinical challenge is early risk stratification for resorptive complications, which profoundly shape prognosis and can necessitate invasive interventions with psychosocial sequelae. Gregorczyk-Maga et al. identified interleukin profiles in gingival crevicular fluid as potential predictors of inflammatory root resorption, pointing toward a molecular diagnostics horizon in which chairside assays could alert clinicians to high-risk biology during the earliest visits [86]. If operationalized as rapid point-of-care kits, such biomarkers could trigger preemptive anti-inflammatory regimens or intensified surveillance schedules, aligning care intensity with individualized risk. The translational pathway will require validation across injury types and ages, standardization of sampling, and pragmatic integration into fast-paced emergency settings, but the promise is clear: molecular signals could sharpen the prognostic lens beyond radiographs and sensibility tests, improving timing and targeting of interventions [86].

Therapeutically, precision adjuncts emerge that may compress healing timelines and diminish pain. Basualdo Allende et al. validated anti-inflammatory effects of low-level laser therapy (LLLT) after replantation, with reductions in pain and improved PDL healing scores relative to sham treatment, positioning photobiomodulation as a safe, child-friendly adjunct in the early post-injury period [76]. Future devices may integrate biosensing to auto-adjust parameters—wavelength, fluence, duty cycle—based on real-time inflammatory markers, yielding "closed-loop" phototherapy that tailors dose to tissue response. Synergies with bioceramic materials are plausible: for instance, combining MTA partial pulpotomy with concurrently titrated LLLT could accelerate dentin bridge formation while dampening inflammatory cascades, potentially shortening the window of vulnerability to infection and reducing the need for more extensive endodontic procedures. Such combinatorial regimens will need randomized validation but align with a broader trend toward multimodal, minimally invasive care that privileges tissue preservation and child comfort [76]. Methodological challenges also constrain the evidence base. Cross-sectional snapshots, including the esthetic and treatment-timing patterns documented by Elizabeth et al. in avulsed and traumatized incisors, provide critical prevalence signals but cannot resolve long-term trajectories or causal mechanisms [79]. To address this, future research should prioritize prospective, multicenter cohorts with standardized imaging (including low-dose CBCT where indicated), digital 3D intraoral scans for surface loss and displacement quantification, and perfusion-based pulp vitality monitoring. Embedding ecological momentary assessment of pain, function, and social participation—captured via mobile health tools—would enable a more granular mapping of the recovery arc and its psychosocial inflections. Layering machine learning onto these rich data streams could yield predictive models that personalize prognosis: for example, integrating intrusion depth, root maturity, occlusal force vectors from pressure-mapping, and early perfusion indices to estimate risk of necrosis or resorption, thereby tailoring recall intervals, counseling, and preemptive therapies. Given the gendered and socioeconomic disparities in treatment delay and mouthguard adoption, equity-sensitive design—oversampling underserved populations, measuring caregiver literacy, and assessing intervention usability—should be a core feature of these studies to ensure generalizability and impact [14,20,79,84,85].

Finally, systems-level barriers persist. Even when clinical teams are highly trained, delays in presentation, fragmented care pathways between schools and dental services, and financial or logistical constraints can prolong visible disfigurement and pain, deepening psychological harm. Practical steps include formalized “dental trauma pathways” that link school nurses and emergency departments to pediatric dental clinics with rapid-access slots; standing orders for first-line measures (e.g., storage media guidance, splint triage); and teleconsultation capacity that leverages tools like ToothSOS and vetted AI copilots to support decision-making during off-hours [82–85]. Family-centered care should be normalized, with structured education at discharge, written action plans, and proactive follow-up calls to support adherence to splint care, diet modification, and revisit schedules. For children with ASD or other neurodevelopmental conditions, desensitization visits, sensory-adapted environments, and collaboration with behavioral therapists can mitigate DFA and improve procedural success, translating into better healing and shorter periods of socially conspicuous impairment [80,81]. In sum, pediatric dental trauma exerts a heavy psychological toll that is inseparable from clinical course and care context. Evidence shows that esthetic disruption restricts smiling and social engagement, pain and function impairments depress OHRQoL, and fear and anxiety are potentiated by knowledge gaps and recent painful experiences [7,79–81]. Closing the loop requires prevention and response systems that are simultaneously biologically astute and psychosocially attuned: education that equips first-line adults to act decisively; policy that converts mouthguard awareness into routine use; technology that delivers point-of-injury guidance; and research that pairs molecular diagnostics with precision adjuncts such as LLLT and bioactive materials [14,20,76,82–86]. As these elements converge, the goal is not only to preserve teeth but to preserve childhood—confidence in smiling, ease in social spaces, and trust in care encounters. Delivering on that promise will mean building trauma pathways that measure success by both radiographic healing and restored quality of life, ensuring that the invisible injuries of fear, shame, and isolation heal alongside the visible tooth.

Conclusion:

In conclusion, addressing pediatric traumatic dental injuries requires an integrated strategy that transcends traditional dental care. The substantial prevalence and potential for long-term complications—ranging from pulp necrosis and root resorption to significant psychosocial distress—underscore the necessity for a cohesive, system-wide response. Effective management hinges on accurate, timely diagnosis utilizing advanced perfusion-based technologies and guideline-driven treatment that prioritizes pulp preservation, particularly in developing permanent teeth. Critically, the clinical approach must be underpinned by robust public health and nursing initiatives focused on prevention. This includes community education to empower parents, teachers, and coaches as effective first responders, alongside policy measures to promote the use of protective equipment like mouthguards. By forging strong collaborative networks between dental professionals, nurses, school systems, and public health bodies, healthcare systems can significantly reduce the burden of TDIs. This multidisciplinary model ensures not only the restoration of dental function but also the safeguarding of a child's psychological well-being and overall quality of life, paving the way for more equitable and comprehensive pediatric oral healthcare.

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