Case Report

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Advanced Wound Management in a Pediatric Hallux Crush Injury With Exposed Bone: A Case Report

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Abstract

Introduction. Complex pediatric hallux injuries with exposed bone are associated with an increased risk of infection and impaired wound healing. Evidence regarding advanced wound care strategies for traumatic wounds in pediatric populations remains limited. This case report aimed to describe the management and healing outcomes of a complex pediatric hallux injury treated with a structured wound care protocol including polyhexamethylene biguanide (PHMB)-based cleansing and dialkylcarbamoyl chloride (DACC)-coated dressings.

Case Presentation. We report the case of a 13-year-old boy presenting with a crush injury of the left hallux characterized by distal phalanx fracture, complete nail avulsion, soft tissue loss, and bone exposure. Following surgical debridement, wound management included PHMB-based cleansing and DACC-coated dressings. During the healing process, hypergranulation tissue developed and was managed with targeted silver nitrate application.

Follow-up and Outcomes. Progressive granulation tissue formation was observed by day 20, with subsequent wound closure and complete epithelialization between days 50 and 70. No clinical signs of infection or other wound-related complications were observed during follow-up.

Conclusion. This case suggests that a wound care strategy incorporating DACC-coated dressings may represent a feasible option for managing complex pediatric traumatic wounds with exposed bone. The favorable healing course and absence of clinical infection support further investigation of this approach, particularly as a strategy aimed at limiting unnecessary antimicrobial exposure.

Keywords: Pediatric, Injury, Trauma, Wound

Introduction

Traumatic hallux injuries in pediatric patients, particularly those caused by crush mechanisms, represent a complex clinical condition frequently associated with nail avulsion, soft tissue loss, distal phalanx fracture, and bone exposure (Jester et al., 2023; Venkatesh et al., 2020). These features increase the risk of infection and may impair wound healing, with potential long-term consequences such as functional limitation, chronic pain, and nail deformities, especially in growing patients (Jaffar et al., 2022). Effective management requires a multidisciplinary approach combining surgical treatment and advanced wound care strategies (Al-Mutairi et al., 2024). Wound bed preparation principles emphasize the importance of maintaining a moist, non-cytotoxic environment to promote tissue regeneration (Labib & Winters, 2026; Nuutila & Eriksson, 2021). Dialkylcarbamoyl chloride (DACC)-coated dressings represent a non-pharmacological approach to infection control. Their mechanism is based on hydrophobic interactions that bind microorganisms to the dressing surface, allowing their removal during dressing changes without releasing antimicrobial agents into the wound (Totty et al., 2017). This reduces cytotoxicity and may limit antimicrobial resistance (Nicolosi & Parente, 2023; World Union of Wound Healing Societies, 2022). DACC dressings have shown activity against a broad spectrum of pathogens, including resistant strains such as MRSA and VRE, and may support healing in both acute and chronic wounds (Ciprandi et al., 2022; Husmark et al., 2022; Totty et al., 2017). However, evidence in pediatric populations remains limited, particularly for acute traumatic wounds (McCord & Levy, 2006; Probst et al., 2022). This case report describes the clinical management and healing outcomes of a complex pediatric hallux crush injury with exposed bone treated using a structured wound care approach including DACC-coated dressings. This case report was prepared and reported in accordance with the CARE (CAse REport) guidelines (Gagnier et al., 2014).

Case presentation

Patient Information and Clinical Presentation

A 13-year-old boy presented to the emergency department after sustaining a crush injury to the left hallux during a fall on rocks. His medical history was unremarkable, with no chronic diseases, previous foot injuries, regular medications, or known drug allergies.

Clinical examination revealed a severe crush injury of the distal hallux characterized by complete nail avulsion, extensive dorsal and distal soft-tissue loss, an open distal phalanx fracture, and exposure of the distal phalanx. The wound appeared grossly contaminated, with irregular wound margins and active bleeding. No tendon injury was clinically evident. Distal perfusion was preserved, with no signs of neurovascular compromise on clinical examination, although sensory assessment was limited by pain.

The initial wound assessment documented extensive tissue disruption involving most of the distal hallux, with exposure of the distal phalanx and significant soft-tissue loss (Figure 1A). Because wound measurements were not routinely recorded during the emergency assessment, precise baseline dimensions could not be retrospectively determined.

Diagnostic Assessment

Plain radiographs confirmed an open fracture of the distal phalanx without evidence of proximal extension. The primary clinical concerns included the high risk of local bacterial contamination associated with an open fracture, preservation of the exposed distal phalanx, and restoration of soft-tissue coverage while minimizing the risk of infection. No major diagnostic challenges were encountered during the initial assessment.

Wound Assessment and Documentation

Serial wound assessments were performed throughout follow-up during routine dressing changes and outpatient visits. Clinical evaluation included wound bed appearance, extent of exposed structures, wound edge progression, exudate amount, periwound skin condition, and clinical signs of local infection. Serial photographs were obtained as part of routine clinical documentation following wound cleansing and before application of the new

dressing.

Because standardized wound measurements were not prospectively collected during routine clinical care, exact serial wound dimensions could not be reliably reconstructed retrospectively. Therefore, wound progression was assessed primarily through sequential clinical examination and photographic documentation.

Complete wound healing was defined as complete epithelial coverage of the wound surface, absence of exposed underlying structures, absence of wound drainage, and no further need for active wound dressings.

Therapeutic Intervention and Wound Management

Emergency surgical treatment was performed on the day of injury and consisted of copious irrigation, surgical debridement, and revision of devitalized tissues. Following surgery, a structured wound management protocol was initiated. Systemic antibiotic therapy with oral amoxicillin/clavulanic acid (1 g three times daily) was initiated on the day of surgery and continued for 12 days. Given the contaminated nature of the injury, the presence of an open distal phalanx fracture, and bone exposure, a DACC-coated dressing was selected to assist local bioburden management while preserving a moist, non-cytotoxic wound environment conducive to granulation tissue formation. The primary local objective was preventive bioburden management in a contaminated high-risk wound rather than treatment of an established wound infection. At the same time, maintaining a moist and non-cytotoxic wound environment was considered essential to support progressive granulation over the exposed distal phalanx. Dressing selection was based on multidisciplinary clinical evaluation, taking into account wound contamination, bone exposure, expected tissue viability, and previous clinical experience with DACC-coated dressings in pediatric wound care. The wound was cleansed with a polyhexamethylene biguanide (PHMB)-based solution before each dressing application, and a secondary absorbent dressing was applied according to the level of exudate.

The affected foot was protected using a Talus offloading shoe, and weight-bearing was restricted during the initial healing phase. Dressings were changed every 48-72 hours according to the amount of exudate and the clinical progress of the wound. At each dressing change, the wound was reassessed for tissue viability, granulation tissue formation, epithelial progression, wound edge advancement, exudate characteristics, and clinical signs of infection.

Approximately three weeks after injury, localized hypergranulation tissue developed and was considered to interfere with epithelial advancement. Topical silver nitrate was therefore introduced while maintaining the DACC dressing regimen. Treatment was discontinued once the hypergranulation tissue had resolved and epithelial migration had resumed. The chronological evolution of the wound, including the principal clinical findings, therapeutic interventions, and representative serial clinical photographs, is summarized in Table 1 and Figure 1.

Ethical considerations

Written informed consent was obtained from the patient's parents for publication of this case report and accompanying clinical information.

Follow-up and Outcomes

During the first postoperative week, wound exudate progressively decreased, while no local or systemic signs of infection were observed. Serial clinical assessments demonstrated progressive stabilization of the wound bed with preservation of the exposed distal phalanx (Figures 1B-C).

By approximately day 20, healthy granulation tissue completely covered the previously exposed distal phalanx (Figure 1D). During the subsequent weeks, wound contraction and progressive epithelial advancement were observed from the wound margins. Localized hypergranulation subsequently developed and was successfully managed with topical silver nitrate (Figure 1E). Following treatment, hypergranulation progressively resolved, allowing continued epithelial advancement (Figure 1F).

Between days 40 and 50, the wound demonstrated marked epithelial progression with progressive reduction of the residual wound surface (Figure 1G). Near-complete epithelialization was observed by approximately day 60, and complete epithelial healing was documented at the subsequent follow-up visit without evidence of wound infection, tissue breakdown, or the need for additional surgical

Table 1. Clinical timeline of wound evolution and management.

Timepoint	Wound assessment	Wound bed composition	Bone exposure	Exudate	Infection indicators	Intervention	Clinical response
Day 0	Extensive distal soft-tissue loss with complete nail avulsion and open distal phalanx fracture	Traumatic wound with exposed distal phalanx	Present	Moderate, sanguineous	No clinical signs of infection*	Surgical irrigation, debridement, oral amoxicillin/clavulanic acid, PHMB cleansing, DACC dressing	Initial wound stabilization
Day 3	Early postoperative wound stabilization	Devitalized tissue with early granulation	Present		No clinical signs of infection	PHMB cleansing, DACC dressing	Reduction in exudate and preservation of exposed bone
Day 7	Progressive wound stabilization	Early granulation tissue with residual devitalized tissue	Present	Mild serosanguineous	No clinical signs of infection	PHMB cleansing, DACC dressing	Continued granulation without evidence of infection
Day 21	Healthy wound bed	Predominantly healthy granulation tissue	Covered by	Scant	No clinical signs of infection	Continued DACC dressing	Complete coverage of the exposed distal phalanx
Day 35	Localized hypergranulation	Granulation tissue with focal	Absent	Minimal	No clinical signs of infection	Topical silver nitrate and continued DACC dressing	Hypergranulation managed
Day 42	Progressive epithelial advancement	Granulation tissue with advancing	Absent	Minimal	No clinical signs of infection	Continued DACC dressing	Regression of
Day 56	Advanced healing	Predominantly epithelialized wound with small residual granulating area	Absent	None to scant	No clinical signs of infection	Continued local wound care	Marked epithelial progression
Day 70	Complete wound healing	Complete epithelial coverage	Absent	None	No clinical signs of infection	Clinical follow-up	Complete healing with preserved hallux function

Note. Clinical signs of infection included erythema, local warmth, purulent exudate, malodor, wound deterioration, and systemic signs.

procedures (Figure 1H).

Throughout follow-up, the patient remained clinically stable and tolerated treatment well. No local or systemic complications occurred. At the final clinical evaluation, the patient reported no pain, had preserved hallux function, and had resumed normal daily activities without functional limitation.

Discussion

This case report describes the successful management of a complex pediatric hallux crush injury with soft-tissue loss, exposed bone, and an open distal phalanx fracture treated with surgical debridement followed by advanced wound care using DACC-coated dressings. The wound healed progressively, with complete coverage of the exposed bone by granulation tissue, subsequent epithelialization, and no clinical evidence of local or systemic infection throughout follow-up. Although the outcome of a single case cannot be used to demonstrate treatment effectiveness, the clinical course is consistent with previous



Figure 1. Serial clinical evolution of a pediatric hallux crush injury managed with surgical debridement and advanced wound care. (A, Day 0) Initial traumatic presentation showing extensive distal soft-tissue loss, complete nail avulsion, and exposure of the distal phalanx. (B, postoperative Day 3) Appearance following surgical irrigation, debridement, and revision of devitalized tissues. (C, postoperative Days 7) Early wound evolution with progressive demarcation of devitalized tissue and preservation of the distal phalanx. (D, Day 21) Healthy granulation tissue completely covering the previously exposed bone. (E, Day 35) Localized hypergranulation managed with topical silver nitrate. (F, Day 42) Improvement of hypergranulation with continued epithelial advancement and progressive wound contraction. (G, Day 56) Advanced epithelialization with marked reduction of the residual wound surface. (H, final follow-up, Day 70) Complete epithelial healing with restoration of soft-tissue coverage.

reports describing the role of DACC-coated dressings in reducing bacterial burden through a physical mechanism of bacterial binding without releasing antimicrobial agents into the wound (Husmark et al., 2022; Totty et al., 2017).

In this patient, the choice of a DACC-coated dressing was primarily influenced by the characteristics of the injury. The wound was contaminated, associated with an open fracture, and presented with exposed bone, making local control of bacterial burden an important component of treatment. At the same time, preservation of a moist wound environment without exposing regenerating tissue to topical antimicrobial agents was considered desirable. Previous clinical experience and published pediatric series have suggested that DACC-coated dressings are well tolerated and may represent a useful option in this setting (Ciprandi et al., 2022; McCord & Levy, 2006; Nicolosi & Parente, 2023).

The clinical evolution observed in this case reflects the principles of wound bed preparation and moist wound healing (Nuutila & Eriksson, 2021; Ousey & Cook, 2012). Following surgical debridement, healthy granulation tissue progressively covered the exposed distal phalanx,

after which epithelialization proceeded without interruption until complete wound closure. Maintaining a clean wound bed while preserving tissue viability is considered a key element in the management of complex traumatic wounds (Labib & Winters, 2026; Nuutila & Eriksson, 2021; Ousey & Cook, 2012).

Hypergranulation developed during the proliferative phase and was treated with topical silver nitrate while the DACC dressing regimen was maintained. After treatment, epithelial advancement resumed and healing progressed without further complications. Although silver nitrate is widely used in everyday practice for the management of hypergranulation tissue, the evidence supporting its use in pediatric wound care remains limited, and treatment should be tailored to the clinical characteristics of each wound (McNamara et al., 2020).

Several treatment options are available for complex pediatric traumatic wounds, including silver-containing dressings, iodine-based preparations, negative pressure wound therapy, dermal substitutes, and reconstructive procedures (McCord & Levy, 2006; McNamara et al., 2020). The choice depends on multiple factors, including wound contamination, the extent of tissue loss, exposed structures, patient characteristics, and local clinical experience. In the present case, conservative management following surgical debridement was considered appropriate because tissue perfusion remained preserved, there were no signs of progressive infection, and serial assessments demonstrated steady wound healing.

This report has several limitations. As a single case, it does not allow conclusions regarding the comparative effectiveness of DACC-coated dressings. The favorable outcome should be interpreted in the context of the overall treatment strategy, which included surgical debridement, irrigation, offloading, regular wound assessment, and adjunctive silver nitrate treatment. In addition, microbiological cultures were not performed, preventing objective assessment of changes in bacterial burden during treatment. Finally, most published evidence on DACC-coated dressings is derived from adult populations (Husmark et al., 2022; Totty et al., 2017), whereas pediatric studies remain limited (Ciprandi et al., 2022; McCord & Levy, 2006; Nicolosi & Parente, 2023). Further clinical studies are needed to better define the role of DACC-coated dressings in the management of complex traumatic wounds in children.

Clinical Implications

This case highlights the importance of a structured and closely monitored wound care approach in complex pediatric traumatic wounds with exposed bone. Following appropriate surgical debridement, DACC-coated dressings may represent a non-medicated option for local bioburden management while maintaining a wound environment conducive to granulation and epithelial progression. Serial wound assessment remains essential to identify changes in tissue viability, exudate, infection indicators, and complications such as hypergranulation, which may require targeted management. Although the findings from a single case cannot establish treatment effectiveness, they may inform clinical decision-making and support further evaluation of DACC-coated dressings in pediatric wound care.

Conclusions

This case illustrates the successful management of a complex pediatric hallux crush injury with exposed bone using a multimodal approach including surgical debridement, PHMB-based cleansing, DACC-coated dressings, offloading, and targeted management of hypergranulation. Complete wound healing was achieved without clinical signs of infection or the need for additional surgical procedures. Although no conclusions regarding treatment effectiveness can be drawn from a single case, the observed clinical course supports further investigation of DACC-coated dressings in complex pediatric traumatic wounds.

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