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Case Report

Flap-sparing approach to pediatric hand wound management with acellular dermal matrix, skin grafting and vacuum-assisted closure: a case report

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ABSTRACT

Severe pediatric hand injuries with exposed tendons and vessels have traditionally been managed using flap coverage. Flap surgeries in young children can be technically demanding, associated with donor site morbidity. Emerging evidence supports alternative reconstructive strategies using dermal substitutes and advanced wound therapies. We report a case of a 3-years-old male with a 3×2 cm anterolateral hand laceration exposing thenar muscles, tendons and vessels following road traffic trauma. Initial primary closure failed. The wound was managed with debridement, application of vacuum-assisted closure (VAC) therapy, placement of an acellular dermal matrix (ADM), split-thickness skin grafting (STSG) and VAC reapplication. Functional and aesthetic outcomes were documented. The wound healed with complete graft take and without the need for flap coverage. The patient regained full hand function with satisfactory cosmetic appearance. No complications such as infection, graft loss or contracture were noted at 1 month follow-up. The ADM facilitated neodermis formation over exposed tendons, allowing successful skin grafting. ADM combined with STSG and VAC therapy provided an effective alternative to flap surgery for pediatric hand wounds with exposed structures. This method can simplify management, reduce morbidity and preserve excellent functional outcomes in young patients.

Keywords: Acellular dermal matrix, Pediatric hand trauma, Split-thickness skin graft, Vacuum-assisted closure

INTRODUCTION

Severe hand injuries in children require meticulous management to preserve function and prevent disability. Deep wounds with exposed tendons, neurovascular structures and bones have classically mandated flap coverage for reliable closure.[1]

Flap surgeries (pedicled or free flaps) can provide well-vascularized tissue but are invasive and challenging in toddlers, often necessitating microsurgical expertise and carrying risks of bulkiness, donor site scarring and impact on growth. Indeed, standard teaching has been that skin grafts alone are inadequate for hand defects involving exposed tendon or bone and thus "skin grafting needs to be very limited and restricted" in such cases.[1] However, advances in wound care have introduced alternatives that can reduce the need for flaps. Negative pressure wound therapy (NPWT) widely known by the vacuum-assisted closure (VAC) device has revolutionized management of complex wounds by promoting granulation tissue and controlling infection. Its use has expanded into pediatric populations over the past two decades.[2,3]

NPWT has been shown to be safe in infants and children, with serious complications (e.g., bleeding or sepsis) reported in<1% of cases.[3] In parallel, acellular dermal matrices (ADM) have emerged as effective dermal substitutes to facilitate wound closure. An ADM is a biologically derived scaffold (e.g., processed human or animal dermis) that provides an extracellular matrix for cellular ingrowth and neovascularization, essentially replacing the missing dermal layer.[4] By doing so, ADMs can convert an avascular surface (such as bare tendon) into a vascular bed that can accept a skin graft. Recent studies in adults show that dermal matrix grafts improve healing in complex extremity wounds and burns, with better cosmetic pliability and reduced scarring.[16]

Their use in children, while less documented, is gaining attention. For example, a 2024 case report described successful use of a fish-derived ADM in a 13-months-old's hand burns, achieving complete functional recovery by 3 years follow-up.[4] Likewise, a pediatric cohort study by Adams et al, found that using ADM with NPWT led to high wound healing rates in lower limb trauma, suggesting this combination as a safe alternative to flaps in children.[5]

We report a pediatric hand trauma case managed with VAC therapy, ADM placement and split-thickness skin grafting. This case highlights how the combination of ADM+STSG+VAC can yield excellent outcomes in a toddler's hand wound.

CASE REPORT

A 3-years-old boy presented to the emergency department with a traumatic hand injury following a road traffic accident. He had been a pillion rider on a motorcycle that collided with a tanker. Examination revealed a 3×2 cm complex lacerated wound on the anterolateral aspect of the left hand, with deep exposure of underlying muscle, tendons and vessel branches. Capillary refill in the digits was under 3 seconds and distal perfusion was intact; the radial pulse was palpable. Importantly, motor function and sensation were preserved in all fingers (pin-prick sensation present, no distal nerve deficit), despite the extensive soft tissue loss.

Initial management

In the casualty operating room, the wound was irrigated and debrided of contaminants. Given the exposed tendons, an attempt at primary closure was made by mobilizing skin edges. The laceration was approximated with interrupted sutures over a sterile dressing. Intravenous antibiotics and tetanus prophylaxis were administered. The hand was immobilized and elevated. However, over the next few days the primary closure failed – the central portion of the wound became necrotic and dehisced. This left a raw defect again, confirming that simple closure was inadequate.

Second surgery negative pressure wound therapy application

5 days after injury, the patient was taken for a formal wound debridement under anesthesia. Devitalized subcutaneous tissue at the base of the wound was excised until fresh bleeding margins were obtained. The extensor tendons and muscle bellies in the area, which had been partly exposed. A vacuum-assisted closure (VAC) dressing was applied, consisting of a foam sponge cut to fit the defect and an occlusive adhesive drape, connected to negative pressure suction at 125 mmHg. The VAC dressing was maintained for several days to promote granulation. After 5 days of NPWT, the wound appeared cleaner and well-vascularized with healthy granulation tissue covering much of the previously exposed area.

Figure 1: Pre-operative presentation with open lacerated wound over dorsum of left hand exposing tendons and muscles.

Figure 2: Failure of primary closure with wound necrosis and exposure pre-revision surgery.

Figure 3: Wound bed after initial VAC therapy showing healthy granulation tissue.

Figure 4: Application of acellular dermal matrix over wound bed during surgery.

Figure 5: Split-thickness skin grafting performed over the ADM with meshed skin.

Figure 6: Two-week postoperative follow-up showing successful graft uptake.

Third surgery (acellular dermal matrices placement and Split-thickness skin graft)

Once the wound bed was optimized, a reconstructive closure was performed. In the operating theater, the VAC dressing was removed and the wound was inspected. A portion of the extensor tendon was still visible at the base without granulation coverage. To avoid a flap, we elected to use an acellular dermal matrix. A commercially available ADM patch (acellular collagen scaffold) was cut to size and laid over the defect, draping over the exposed tendon and muscle.

The matrix immediately provided coverage of the vital structures; it was secured to the wound edges with absorbable sutures. Next, a split-thickness skin graft (approximately 0.3 mm thickness) was harvested from the child's left thigh. The skin graft was meshed (1.5:1 ratio) to allow expansion and drainage, then placed over the ADM and surrounding granulation tissue, effectively sandwiching the dermal matrix between the graft and wound bed. The graft was stapled and sutured to the skin edges. To ensure graft adherence and prevent seroma, a VAC dressing was reapplied over the graft (at lower pressure, –75 to –100 mmHg). The leg donor site was dressed with Vaseline gauze. The patient tolerated the procedure well and the hand was immobilized in a cotton-padded splint.

Outcome

The VAC over-graft dressing was removed on post-operative day 5, revealing a well-adhered graft. The underlying ADM had incorporated into the wound, forming a neodermis. The meshed skin graft showed >95% take, with only minimal focal areas of separation. The wound was fully closed with a smooth graft surface; no tendon or subcutaneous tissue was exposed. At two weeks post-grafting, the wound was completely epithelialized.

By 4 weeks, the child had regained full active range of motion in the wrist and fingers. Hand function (grip strength, pinch and fine motor use) was appropriate for age and the child resumed normal play activities. The grafted area was supple and did not restrict movement across the joints. Apart from mild hypopigmentation of the graft versus surrounding skin, the cosmetic result was satisfactory. The donor site on the thigh healed uneventfully. The patient's family was relieved that a more complex flap surgery was avoided. He continues to be followed in outpatient therapy to encourage scar massage and to monitor growth of the hand. No late complications (such as wound breakdown or contracture) have been observed at the 3-months follow-up.

However, wound breakdown occurred with necrosis evident pre-second surgery (Figure 2).

DISCUSSION

Traumatic hand wounds in pediatric patients demand a balance between achieving stable coverage and minimizing long-term morbidity. In adults, coverage of exposed tendons or bones in the hand typically calls for flap reconstruction (local or free flap), as skin grafts alone would not survive on an avascular surface.[1] In small children, however, flap options are limited by diminutive anatomy and potentially higher donor site sacrifice relative to body size.

Even when feasible, flaps may require prolonged immobilization (for example, an abdominal pedicle flap would necessitate the hand being bandaged to the abdomen for 2–3 weeks) and can result in joint stiffness or need for secondary revisions. Microvascular free flaps have been successfully used in children, but these surgeries are lengthy and technically demanding, with risks of failure.[17] Moreover, creating a bulky flap on a tiny hand can impede fine motion and may necessitate debulking procedures later as the child grows. This case demonstrates that the combination of VAC therapy, acellular dermal matrix and split-thickness skin graft can be a limb-saving alternative in pediatric hand wounds. This approach leverages the principles of wound conditioning and tissue engineering to achieve closure:

Negative pressure wound therapy (vacuum-assisted closure)

NPWT was used to convert a contaminated, non-healing wound into a cleaner, well-vascularized bed. The suction-assisted drainage reduces edema and bacterial load while the mechanical micro deformational forces stimulate granulation tissue formation.[2] VAC has been increasingly used in children's wounds ranging from trauma to burns, with large case series confirming its safety and efficacy.[3] In this patient, 5 days of VAC therapy resulted in robust granulation covering most of the hand defect, confirming the expected benefits of NPWT noted in pediatric studies. Without this step, the wound's zone of injury might not have been adequately demarcated for grafting.

Acellular dermal matrix

The application of an ADM allowed us to bridge over the remaining exposed tendon and augment the dermal layer of the wound. Biologic dermal matrices (derived from human or animal sources) act as a scaffold that is gradually infiltrated by the patient's cells and vasculature.[4] This effectively creates a neodermis over structures that lack soft-tissue coverage. By 1–2 weeks, the ADM typically integrates and provides a vascularized surface for epidermal closure. ADM technology was first popularized in burns and has shown superior outcomes compared to grafting alone, such as reduced contracture and a more pliable scar.[16]

In pediatric burn patients, using dermal substitutes under grafts has yielded excellent long-term hand function with minimal contractures.[7] In our trauma case, the ADM prevented the need for a flap by performing the dermal regenerative function. Notably, Adams et al, reported that out of 54 children treated with dermal matrix for limb injuries, 45 healed without complications – all of whom had received NPWT along with the ADM.[18] This underscores that the synergy of ADM with VAC (as we employed) is particularly effective: NPWT both prepares the wound for and enhances the take of the dermal matrix.[5]

Split-thickness skin graft with vacuum-assisted closure dressing

Once the dermal matrix was in place, a thin split-skin graft provided epidermal coverage. Traditionally, a skin graft over a raw tendon would fail; but in this case, the graft was laid over the vascular granulation tissue and ADM, ensuring its survival. We applied the VAC dressing over the fresh graft – a technique shown to improve graft take by stabilizing the graft, removing sub-graft fluid and increasing capillary perfusion into the graft.[18] The result was nearly complete graft uptake in our patient. By comparison, if a flap had been used instead of the ADM+STSG, the child might have faced a bulkier tissue on the hand and a more complex postoperative course. Here, the healed graft was thin and flexible, preserving the delicate contour of the child's hand.

Overall, this case aligns with the growing body of literature advocating modern wound care techniques over more aggressive surgical approaches when appropriate. Our patient's outcome a fully functional hand with good cosmetic skin coverage suggests that ADM+STSG+VAC can yield at least equivalent results to flap coverage in a pediatric hand, without the added donor site morbidity and surgical complexity. It is noteworthy that the flap-less approach also allowed early mobilization; the child began gentle finger movements within a week of grafting, which is crucial to prevent stiffness in hand joints. Early motion of a flap could jeopardize its viability, whereas the bioengineered graft construct was resilient enough to allow rehabilitation.

From a cost perspective, one might argue that dermal matrices are expensive; however, flap surgeries also incur significant cost (operation time, hospital stay) and potential future surgeries. In resource-constrained settings, smaller wounds like this might sometimes be managed by delayed healing and contraction, but on the hand that would lead to severe contractures. ADM plus VAC presents a viable middle ground using advanced dressings to achieve closure that maximizes function.

One limitation to note is that long-term outcomes in growing children need further study. The grafted skin will not grow like normal skin, so careful follow-up is needed to monitor for any contracture as the hand enlarges. Nonetheless, literature on pediatric burn scars treated with ADM has shown durable results up to 10 years, with low contracture rates. We anticipate similarly favorable remodeling in our trauma patient given the pliability of the reconstructed skin. If any issues arise, minor revisions (like releasing a tight band) could be done, but importantly the foundational coverage is solid.

CONCLUSION

Pediatric hand trauma with exposed tendons is traditionally managed with flap surgery, but this case illustrates an effective alternative using acellular dermal matrix, split-thickness skin grafting and VAC therapy. The combined approach promoted wound healing and provided stable, supple coverage without the morbidity of a flap. Our patient achieved an excellent functional and cosmetic outcome. Emerging evidence supports that ADM with NPWT can safely substitute for flaps in selected pediatric wounds. We suggest that in pediatric hand injuries, especially when local tissues are insufficient, a strategy of wound bed preparation with NPWT followed by ADM plus skin grafting should be considered. This technique can simplify management and lead to superior pediatric outcomes, making it a valuable addition to the reconstructive toolkit in orthopedic and plastic surgery practice.

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