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The combined ALT–groin flap for the mutilated and degloved hand

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ABSTRACT

Background: Degloving and mutilation of the hand is a rare but formidable challenge. When replantation is not possible, we rely on distant pedicled flaps. We present a technique using pedicled anterolateral thigh (ALT) and groin flaps to sandwich and resurface the degloved hand. The purpose of this study is to describe the rationale, indications, methods and outcomes of combined pedicled ALT and groin flap reconstruction of the degloved hand.
Methods: Five injuries were treated at this center between 2011 and 2014. Charts were retrospectively reviewed and outcomes evaluated. Four ALT–groin flaps were performed in a single stage for degloving, crush and combined injuries. In one case, partial necrosis of a tight groin flap necessitated secondary ALT coverage at a second stage.
Results: Flaps survived after division at 4 weeks, and venous congestion was not observed at any point. Debulking, syndactyly release and toe transfer followed reconstruction to enhance outcomes.
Conclusions: The combined ALT–groin flap is safe and feasible for the reconstruction of the degloved or mutilated hand when replantation is not an option. It is attractive for familiar donor anatomy, donor-site morbidity and the quantity and composition of the tissue it provides.

Background

Degloving injuries of the hand are rare but alarming (Supplemental Digital Content: Video 1). As the soft tissue envelope supplies blood to the distal hand, ischemia and necrosis of the denuded parts may be imminent without expedient vascularised tissue transfer. In the spirit of replacing like with like, replantation is ideal but often impossible [1–4]. Even when amputated and degloved parts are available, neurovascular trauma at multiple levels and an extensive zone of injury deem flap survival and functional restoration unlikely. If degloving is accompanied by amputation (Fig. 1), dependable tissue coverage provides a platform for digital reconstruction and toe-to-hand transfer (Fig. 2A–D) [5–7].

The perfect reconstructive strategy would restore intricate hand functions and a specialised anatomy; the current methods, including replantation, fall short in both categories. Distant pedicled options from the groin and abdomen have been favoured since the 1970s. These methods do not require a microsurgical technique and they permit a two-team approach. Groin flaps are reliable, provide ample tissue, are easy to harvest and exhibit minimal donor-site morbidity. However, they may not cover extensive defects that involve the dorsal and palmar hand, particularly without a time-consuming delay procedure or tissue expansion [8]. Paired groin and abdomen flaps have been described since the 1970s [2,5,9–18], which are better suited to extensive and three-dimensional wounds.

Because degloving injuries of the hand are infrequent, the literature scarcely supports a single technique for secondary reconstruction and no comprehensive reviews or meta-analyses exist. There seems to have been little evolution in reconstructive technique since the 1970s, and to our knowledge no gold standard exists. The anterolateral thigh (ALT) flap has a long-standing heritage as a workhorse free [19] and pedicled flap [20], yet it was only recently that the pedicled ALT flap was described for hand reconstruction. Tuncer was the first to use it in upper-extremity reconstruction in 2008 [21]. Three years later, Senda combined a pedicled ALT and groin flap, providing additional volume and improved coverage for complex defects [17].

Senda described the only report of the combined use of ALT and groin flaps in the literature, to the author's knowledge [17]. We modified Senda's technique to enhance reliability and outcomes. The purpose of this study is to retrospectively review a series of cases where pedicled ALT and groin flaps were used for reconstruction following degloving injury. We aim to provide rationale, indications and methods for combined ALT–groin flap

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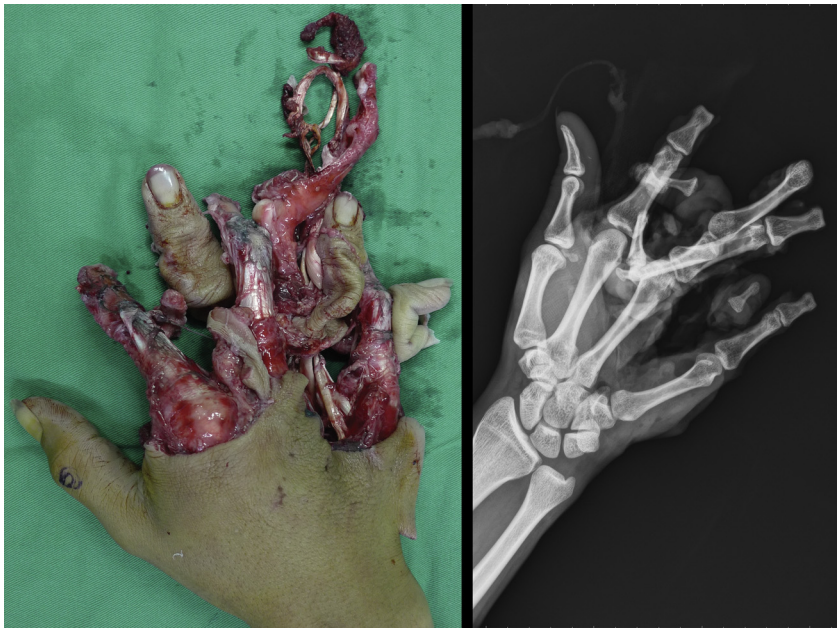

Fig. 1. Representative presentation of crush and degloving injury. Destruction of bone, tendon, muscle, nerves, blood vessels and skin (left) pose a formidable reconstructive challenge. (Right) PA plain film of the same hand illustrates the severity of the injury. The outcome is shown in Fig. 4.

coverage. Finally, we critically analyse outcomes of the ALT–groin flap reconstruction of the mutilated hand.

Methods

Between October 2011 and May 2014, five mutilated hands in four men and a woman ranging from 23 to 38 years (average, 31.6 years) were treated at this center with a combined ALT–groin flap. The mechanisms were crush–degloving injury (three cases), pure crush (one case) and pure degloving without bone loss (one case). The proximal extent of injury was the metacarpal shaft (two hands), wrist crease (one hand), metacarpal base (one hand) and the metacarpophalangeal joint (MPJ) (one hand). The entire bony skeleton was preserved in one case. In the remaining hands, there were varying degrees of bony amputation. Management included debridement, bony stabilisation and early flap coverage in four cases. In one case, the injury was debrided at an outside hospital and definitively covered 40 days later in two stages (Table 1).

Preoperative considerations

Efforts were made to replace and replant degloved and amputated tissue. Avulsed tissues were carefully debrided and loosely replaced. Unstable or unusable tissue was thinned, defatted and applied as a skin graft. Bony, ligamentous and tendinous reconstruction was performed as needed. MPJs were temporarily

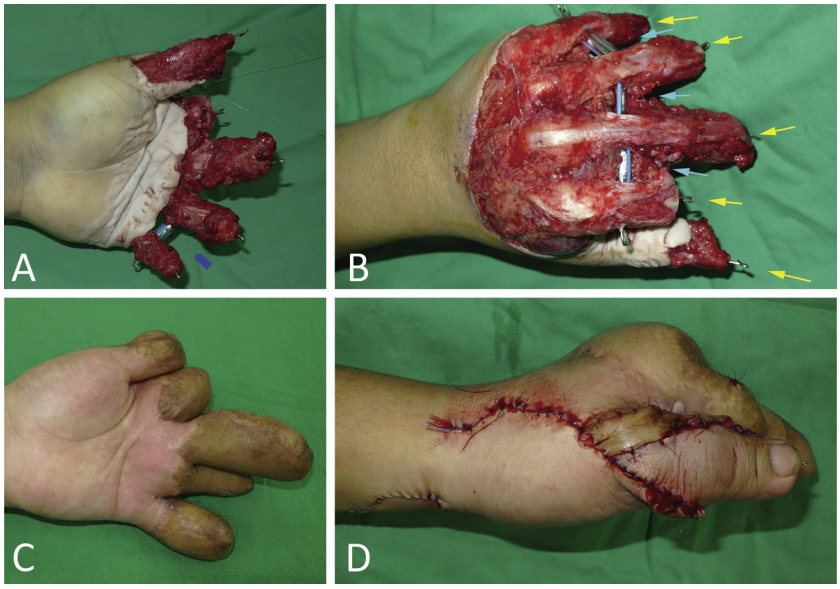

Fig. 2. A toe-to-thumb transfer enhances function in a hand after mutilating injury. (A, B) After meticulous debridement, transverse and longitudinal stability is achieved with interdigital spacers (hard plastic tubing fixed with Kirschner wires, blue arrows) and Kirschner wires (yellow arrows). (C) Soft tissue augmentation with pedicled flaps provided protection for underlying vessels, preserved existing vessels for use in toe-to-thumb transfer, and provided a soft tissue pedestal to facilitate subsequent reconstruction. (D) Result of second-toe wraparound coverage of degloved thumb. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

Table 1
Patient information.

Age sex	Mechanism	Extent	Musculoskeletal involvement	Initial management	Surgery date	Flap division	Complications	Additional surgery	Function	Follow-up (days)
35F	Crush	MPJ Thumb	Thumb amputation IF ray amputation MF MPJ amputation	Debridement at OSH	9/28/11 groin 11/9/11 ALT	3 weeks groin 4 weeks ALT	Partial groin flap necrosis (50%)	1, 2: Syndactyly release 3: Toe–thumb transfer	PIP PROM 40–100 AROM 60–100	621
32M	Crush Deglove	All fingers Palm	RF ray amputation IF, MF, SF degloving to MPJ MF MPJ ligament injury	K-wire Debridement Ipsilateral sandwich	4/2/13	5 weeks	Nil	1,2: Syndactyly release 3: 1st web space release 4: Syndactyly release	–	517
38M	Crush Deglove	Volar to MPJ Dorsal to wrist	IF, MF amp to MCP RF amp at PIP SF amp at DIP	K-wire Fasciotomy, STSG Ipsilateral sandwich	4/21/13	4 weeks	Nil	1: Syndactyly release 2: Tenolysis	2–5 MPJ AROM 75 Thumb abduction 60	484
23M	Deglove	Volar to MPJ Dorsum to wrist	Degloving to MPJ IF amputation at PIPJ MF P2 fracture	K-wire Ipsilateral sandwich	1/24/14	3 weeks	Nil	1: Syndactyly release	Thumb MPJ PROM 0 2–5 MPJ 10–30 PROM	218
30M	Crush Deglove	MF, RF, IF to MPJ Palm	MF MC base fracture MF, RF PIPJ fracture dislocation	ORIF MF MC base and IF PIPJ Repair MF PIPJ ligaments Ipsilateral sandwich	5/4/14	3 weeks	Nil	1: Tenolysis 2: Syndactyly release	–	115

IF, index finger; MF, middle finger; RF, ring finger; SF, small finger; MC, metacarpal; MCP/MPJ, metacarpophalangeal joint; PIP(J), proximal interphalangeal (joint); P1, 2, 3, proximal, middle, distal phalanx; ORIF, open reduction internal fixation; STSG, split-thickness skin graft; OSH, outside hospital; A/PROM, active/passive range of motion.

stabilised in the functional position. In some cases, interdigital transverse stabilisation was achieved with plastic tubing held in place with pins to prevent web and soft tissue contracture (Fig. 2A, B). The relative indications for reconstruction were as follows: (1) the amputated tissue envelope was not preserved, (2) previous reconstruction efforts failed, (3) vascular tissue was required in the first stage (i.e., there was hardware present), (4) the patient had a near-total or total degloving defect at or beyond the MPJ and [5] toe-to-hand transfer was planned.

Combined ALT–groin flap

The ipsilateral groin was raised for first web space and palmar reconstruction. The flap was tailored to the defect, overcorrecting for volume. The ALT was designed and raised next (Fig. 3). The flap was raised as a composite fasciocutaneous flap [22]; the fascia lata was included with the ALT to provide a smooth gliding surface for extensor excursion. The ALT incision was extended cephalad to the groin wound to facilitate delivery of the flap. Dissection of the pedicle was taken as far proximally as necessary to accommodate tension-free inset. The proximal ALT flap was anchored to the thigh or base of the groin flap to avoid tension on the pedicle. The hand was positioned with a hand-in-pocket posture; the groin and ALT flaps lined the volar and dorsal surfaces, respectively and in that order (Fig. 4). The groin flap was tubed as needed to eliminate raw surface exposure and protect the pedicle.

Donor sites were closed in layers over closed suction drains soon after the flaps were raised to minimise edoema and facilitate primary closure. The flaps were monitored for changes in colour, turgor and temperature without specialised instruments. When there was concern, bleeding was evaluated with superficial scoring of the skin using an 18-gauge needle and irrigating with heparinised saline solution. No effort was made to identify or monitor perforators using Doppler. The donor extremity was monitored for signs of neurovascular injury and compartment syndrome.

Division

Flaps were divided at 4 weeks following reassuring intraoperative perfusion assessment.

Results

Reconstruction was performed in a single stage on the day of injury (one case), 2 days (two cases) and 3 days later (one case). In one case, a groin flap was used to cover a wound 40 days after presentation, which was complicated by 50% flap loss because of tight coverage of a large defect. An ALT flap was used to cover the resulting wound 42 days later, completing the flap 'sandwich' in two stages. The postoperative course was smooth thereafter, without vascular insufficiency or flap necrosis. Single-stage reconstructions were divided at 3 weeks (two cases), 4 weeks (one case) and 5 weeks (one case). Dehiscence at the flap division site in one case healed after debridement of granulation tissue and closure. In another, a localised allergic reaction resolved without issue.

In every case, syndactyly between fingers was performed in one (three cases) or two stages (two cases) using zigzag incisions similar to those used in congenital hand surgery. In three hands, syndactyly between the middle and ring fingers was released and no further divisions were performed. A middle–small finger syndactyly was divided first in one hand that was missing a ring finger. In that same case, an index–middle syndactyly was released in a second stage. A middle–ring release was performed first in one case with an index finger ray amputation followed by ring–small division. In the same case, a second toe-to-thumb wraparound

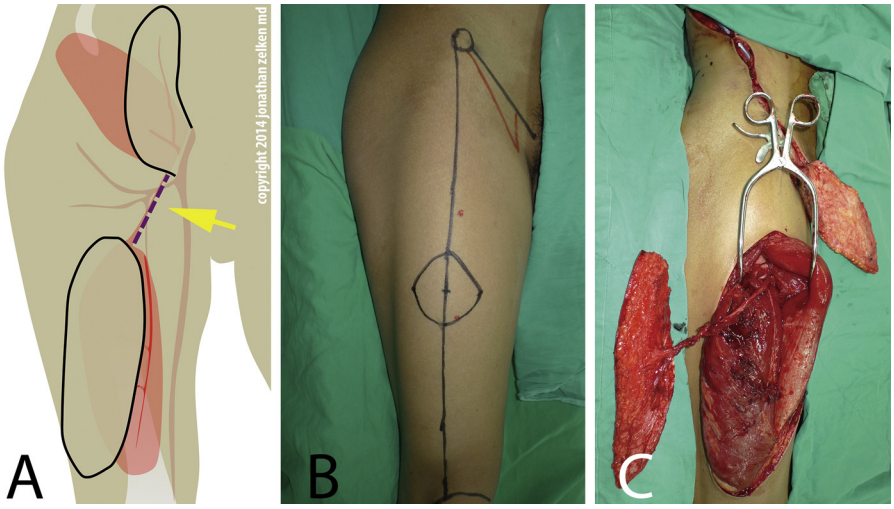

Fig. 3. Design. (A) Representative layout and vascular axis identification (B) for combined ALT–groin flap. The purple dashed line (yellow arrow) creates a continuous plane between the suprafascial groin flap and ALT flap wounds, permitting delivery of the ALT flap through the proximal wound (C). This is intended to increase ALT flap mobility, efficiency and pedicle length. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

flap was transferred in a third stage (Fig. 2). No additional complications occurred. An average of 1.8 revision procedures were performed (range, 1–4 procedures) per case. Other refinements included tenolysis (two cases) and soft tissue contracture release (two cases).

Joint motion was evaluated in three of five cases at the most recent follow-up (Table 1). In one case, a reconstructed right proximal interphalangeal (PIP) demonstrated 40–100° of passive motion and 60–100° of active motion at 1.7 years. In another injury that involved all the digits, the thumb had no MPJ motion, and the remaining MP joints were severely restricted to 10–30° of active motion at 8 months. In a third case, the second through fifth MP joints had 75° of active flexion and the thumb could adduct at the MPJ to 60° at 1.3 years. Average duration of follow-up from reconstruction to the most recent follow-up was 391 days (range 115–621 days). Wide variations in functional outcomes reflected the severity of initial trauma.

Discussion

Degloving injuries may result in extensive tissue loss, few available recipient vessels, disfigurement and significant functional impairment. Goals of reconstruction are preservation of length, improvement of appearance and restoration of function. To achieve this, adequate soft tissue coverage should be established early. Secondary procedures such as toe-to-hand transplantation enhance appearance, enable key pinch and improve grip strength. We currently favour the use of combined pedicled ALT and groin flaps to reconstruct degloving injuries. We describe the rationale, indications, methods and outcomes of our preferred strategy.

The important benefit of pedicled flap coverage of the mutilated hand is preservation of existing blood supply. Pedicled flaps do not necessitate a microsurgical technique and specialised postsurgical care, and they permit a two-team approach for debridement and flap harvest. The pedicled groin flap is reliable and boasts a large

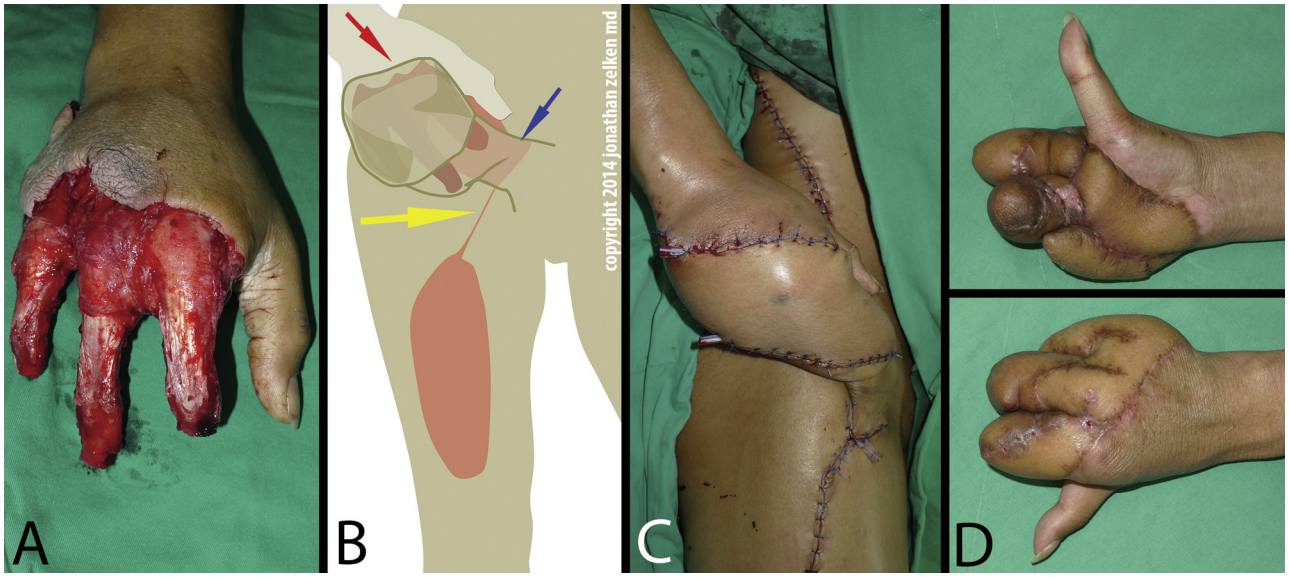

Fig. 4. Inset and division. (A) Crush and degloving injury as seen in Fig. 1, following debridement. (B) The pliable groin flap (blue arrow) provided palmar coverage. The ALT (red arrow) pedicle was dissected as proximally as possible (C), delivered through the wound extension (yellow arrow) and gently draped over the dorsum, providing total wound coverage. (C) The tissues were closed in a tension-free manner. (D) Postoperative view after two syndactyly releases and debulking. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of the article.)

skin paddle, facile harvest, minimal donor-site morbidity and an inconspicuous scar. However, this flap will not cover extensive dorsal and volar hand defects, particularly without time-consuming delay procedures or tissue expansion [8]. Extensive tissue loss warrants multiple-flap reconstruction [9,10,12,14,15,17,18]. The pedicled ALT flap was not described in hand reconstruction before this decade [21,23]. However, historical references [17,21] and our experience support the feasibility of the ALT in pedicled hand coverage. The combination of groin and ALT flaps provides a substantial amount of tissue.

Candidates for surgery suffered traumatic degloving injuries, often with a crush component whose replantation efforts, if attempted, had failed. We strived to create a pliable and sensate envelope that preserved joint excursion, blood supply and digital length. Manifestations of degloving injury are different from blast and pure crush injuries as the soft tissue envelope is disproportionately injured. In some cases, soft tissue is all that needs replacement: nerves, tendons, pulleys, ligaments and skeletal tissue proximal to the DIP joints are often preserved. When soft tissue coverage is replaced early, the functional length of the fingers and range of motion (ROM) of MPJs may be maximised, and basic hand function can be achieved with fewer subsequent procedures. The alternative options to this technique include amputation and prosthesis, free flaps and local pedicled flaps.

From a sociocultural prospective, the Taiwanese typically prefer limb preservation to amputation, as do most Asian populations. There are important economic considerations as well. In the lower-extremity literature, the cost of salvage was shown to be lower than amputation at 2 years. The disparity widens over the lifetime of the patient, where prostheses eventually cost three times as much as reconstruction [24]. Many patients we treat for degloving injuries are young labourers who cannot afford prohibitive lifetime costs of maintaining and replacing prostheses. When there is incomplete degloving, or at least one digit is preserved, sensory outcomes are always superior to amputation and prosthesis. Ultimately, the decision to amputate is the responsibility of the consultant surgeon and it should reflect the patient's other injuries, quantity and function of the salvaged tissue, patient motivation and wishes, surgeon expertise and resources. We cannot claim whether functional return after reconstruction is superior to early amputation and prosthesis fitting.

This technique relies on intact and uncompromised donor tissue, which may not be available. In theory, the contralateral hip may be used if the ipsilateral tissue is absent or unreliable. Neumeister et al. provide an exhaustive summary of alternatives for mutilated hand reconstruction [25]. Free tissue options such as the latissimus dorsi are capable of covering large areas, and the serratus flap is effective for smaller defects. The temporal parietal flap is classically described for dorsal hand coverage for its pliability, dependability and amenability to tendon excursion [26,27]. Numerous free tissue options are available.

We do not favour free tissue transfer, because we prefer not to exploit vessels or compromise perfusion. Local pedicled options include the reverse radial forearm flap, interosseous flaps and the Becker (ulnar artery) flap. The forearm flap entails proximal division of the radial artery, and the latter options are small and may not reach. Other options including the omentum, abdomen and spare parts may play a role in future applications, but they have not been widely used in the literature or at our institution. Distant pedicled flaps can be ergonomic, dependable and generous in quantity. For reasons we mentioned, a combination of ALT and groin flaps is an attractive option.

Combining pedicled groin and ALT flaps provides abundant tissue that exceeds other combinations in that region. Senda introduced this concept [17], but we present the first series and modified the design. Venous congestion and partial necrosis described in Senda's report probably resulted from a vulnerable, bare pedicle that kinked at the flap–thigh junction. To optimise the ALT pedicle position, we first inset the pliable groin flap in the palm, and then gently draped the ALT flap over the dorsum [21]. We avoided folding the ALT to optimise flap perfusion and efficiency. We anchored the ALT to the thigh and groin flap with heavy-gauge suture after mobilisation and inset to minimise further risk of mechanical trauma and kinking.

No delay procedures for flap training were needed in our series, and the vascular pedicle was patent upon division in every case. We divided flaps at 3–4 weeks with success, as did Tuncer and Senda [17,21]. There is room for improvement in flap coverage of the degloved and mutilated hand; superthin [28–32] elevation and primary defatting may enhance cosmetic and functional outcomes. We acknowledge that the final product is not always cosmetically appealing and functional outcomes are equivocal at best. This is evidenced by unsatisfactory parameters documented after three successful reconstructions. Aesthetic results may be enhanced with staged excision and liposuction [33], but excessive debulking can further impair mobility and perfusion.

The series is important in establishing the feasibility of combined ALT and groin flaps for coverage of extensive and complex defects. It is the first series to review these flaps. We clearly identify the rationale of a modified design and suggest strategies for subsequent refinements, such as toe transfer and division of syndactylous digits. The important limitations of this series include small sample size, varying degrees and patterns of injury and failure to evaluate patient satisfaction. Most importantly, the outcomes were not compared with alternative strategies that are currently in use. This can largely be attributed to the rarity of degloving injuries encountered globally.

Future studies may compare the economic, cosmetic, functional and psychological aspects of pedicled versus free flap reconstruction, salvage versus amputation, vascularised composite allotransplantation, etc. For now, the combined ALT–groin flap is our preferred method when enough tissue remains to restore basic hand function. We endorse this straightforward and feasible strategy using workhorse flaps that offer acceptable donor-site morbidity, abundant tissue and a concealable scar.

Conflicts of interest and source of funding

None of the authors has a financial interest in any of the products, devices, or drugs mentioned in this manuscript.

This work has not been presented at any meetings or symposia.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.injury.2015.05.022.

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