McGraw J. Reed (Orcid ID: 0000-0003-2394-2212)
Othman Sammy (Orcid ID: 0000-0002-8814-1048)
Mauch Jaclyn T (Orcid ID: 0000-0002-1590-733X)

Free Flap Reconstruction of Elbow Soft Tissue Defects: Lessons Learned from Fifteen Years of Experience

J Reed McGraw, BS[1*], Reena S Sulkar, MBA[1*], Corey M Bascone, MD, MBA[1], Sammy Othman, MD[2], Jaclyn T Mauch, MD, MBE[3], Hani I Naga, MD[4], L Scott Levin, MD[1,5], Stephen J Kovach, III, MD[1,5]

1. Division of Plastic Surgery, Department of Surgery, Hospital of the University of Pennsylvania, Philadelphia, PA, USA
2. Division of Plastic and Reconstructive Surgery, Department of Surgery, Northwell Health, Great Neck, NY, USA
3. Section of Plastic Surgery, Department of Surgery, University of Michigan, Ann Arbor, MI, USA
4. Division of Plastic, Reconstructive, Oral, and Maxillofacial Surgery, Department of Surgery, Duke University Medical Center, Durham, NC, USA
5. Department of Orthopaedic Surgery, Hospital of the University of Pennsylvania, Philadelphia, PA, USA

* Co-first author

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Corresponding Author:

Stephen J. Kovach, III, MD
Herndon B. Lehr, MD Endowed Associate Professor in Plastic Surgery
Division of Plastic Surgery
3400 Civic Boulevard
Perelman Center for Advanced Medicine
14th Floor, South Tower
Philadelphia, PA 19104
Office: (215) 662-7300
Fax: (215) 615-0474
Email: Stephen.kovach@pennmedicine.upenn.edu

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Abstract

Background: The elbow is a complex joint that is vital for proper function of the upper extremity. Reconstruction of soft tissue defects over the joint space remains challenging, and outcomes following free tissue transfer remain underreported in the literature. The purpose of this analysis was to evaluate the rate of limb salvage, joint function, and clinical complications following microvascular free flap coverage of the elbow.

Methods: This retrospective case series utilized surgical logs of the senior authors (S.J.K and L.S.L) to identify patients who underwent microvascular free flap elbow reconstruction between January 2007 and December 2021. Patient demographics and medical history were collected from the medical chart. Operative notes were reviewed to determine the type of flap procedure performed. The achievement of definitive soft tissue coverage, joint function, and limb salvage status at one year was determined from postoperative visit notes.

Results: Twenty-one patients (14 male, 7 female, median age 43) underwent free tissue transfer for coverage of soft tissue defects of the elbow. The most common indication for free tissue transfer was traumatic elbow fracture with soft tissue loss [n = 12, (57%)]. Among the 21 free flaps performed, 71% (n = 15) were anterolateral thigh flaps, 14% (n = 3) were latissimus dorsi flaps, and 5% (n = 1) were transverse rectus abdominis flaps. The mean flap size was 107.5 cm^2. Flap success was 100% (n = 21). The following postoperative wound complications were reported: surgical site infection [n = 1, (5%)]; partial dehiscence [n = 5, (24%)]; seroma [n = 2, (10%)]; donor-site hematoma [n = 1, (5%)]; and delayed wound healing [n = 5, (24%)]. At one year, all 21

patients achieved limb salvage and definitive soft tissue coverage. Of the 17 patients with functional data available, 47% (n = 8) had regained at least 120 degrees of elbow flexion/extension. All patients had greater than one year of follow-up.

Conclusion: Microvascular free flap reconstruction is a safe and effective method of providing definitive soft tissue coverage of elbow defects, as evidenced by high rates of limb salvage and functional recovery following reconstruction.

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Introduction

The elbow is a critical anatomic region, as adequate flexion, extension, pronation, and supination at this joint are necessary for effective utilization of the upper extremity. Furthermore, a number of vital blood vessels, nerves, and tendons that supply the forearm and hand traverse the joint (1). Given this unique function and anatomy, the surrounding soft tissue envelope protecting the joint space is necessarily both durable and pliable. The posterior elbow features thickened skin to facilitate adequate support given the load-bearing nature of the joint. At the same time, native elbow soft tissue is highly pliable to facilitate functional range of motion (2–4).

As a result, soft-tissue defects of the elbow can carry significant morbidity, and for the reasons outlined above, remain difficult to treat (5). These defects may arise from a variety of causes such as trauma, underlying infection, and malignancy (6). Adequate reconstruction must ensure both durable and pliable soft-tissue coverage to maintain functional range of motion and sufficiently cover underlying bone, muscle, tendon, and nerve. Often, soft tissue defects in this region are seen in conjunction with bony injury in the case of trauma, and as such, warrant an orthoplastic reconstructive approach. This challenge is heightened by the thinness of the soft tissue envelope surround the medial and lateral aspects of the humerus, putting the ulnar nerve and triceps tendons in jeopardy if the envelope is compromised. Coverage options broadly include primary closure, local fasciocutaneous flaps (e.g. medial or lateral arm/forearm flaps), local muscular flaps (e.g. anconeus flap, brachioradialis flap), regional pedicled flaps (e.g. latissimus dorsi flap, thoracodorsal perforator flap), distant pedicled flaps (e.g. paraumbilical perforator flaps), and free

tissue transfer (5,7–13). In addition to patient comorbidities and other patient selection factors that are predictive of successful reconstruction, size of the defect, etiology of the wound, and the presence of concomitant bony and neurovascular injury are important considerations when selecting the optimal method for achieving definitive soft tissue coverage (2,3,5,6,14,15).

Previous studies have demonstrated the benefits of various local flaps and regional pedicled flaps for elbow reconstruction (8,10–12,16–19). However, high rates of reoperation and unsuccessful definitive coverage following total elbow arthroplasty have been reported, resulting in subsequent free flap reconstruction (14,15). For example, pedicled latissimus dorsi flaps are often limited by deficient pedicle length and are often unable to provide sufficient elbow coverage, particularly in cases of olecranon fracture (20). As such, there has been growing interest in bypassing lower rungs of the reconstructive ladder and proceeding directly to microvascular free flap coverage, as providing more tissue bulk can better support subsequent limb salvage procedures and functionality of the joint as a whole (6,7,21–23). The choice of flap can then be tailored to the defect and aid in avoiding donor site morbidities that may interfere with additional orthopedic interventions, such as external fixation (2,6). The most reported free flap types utilized for elbow soft tissue coverage include, more traditionally, free muscle flaps [e.g., latissimus dorsi and transversus rectus abdominis myocutaneous (TRAM) flaps] and more recently, free fasciocutaenous flaps [e.g., anterolateral thigh (ALT) and superficial circumflex iliac artery perforator (SCIP) flaps] (22,24,25).

A variety of microvascular techniques exist for providing soft tissue coverage of the joint, and these approaches may vary by surgeon and by patient. The body of literature surrounding the use of local flaps for the coverage of elbow defects is well described (5–7,14,26); however, the literature on free tissue transfer to the elbow is relatively limited to small case series and case

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reports (21,22). The purpose of this case series was to further explore the role of microvascular free flap coverage for elbow defects as it applies to both limb salvage and functional joint status in an effort to promote improved patient outcomes.

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Methods

This retrospective cohort series received approval from the review board on human research at the Hospital of the University of Pennsylvania (IRB # 852232), and the requirement for informed consent was waived. The surgical logs of the senior authors (S.J.K. & L.S.L) were queried for all cases of free flap coverage of soft tissue defects of the elbow from January 2007 to December 2021. Patients were excluded if they were under the age of 18 or if soft tissue coverage was achieved without the use of free tissue transfer. Patient and surgical data was obtained from the electronic medical record. Electronic medical records were reviewed to extract relevant patient demographics, surgical characteristics, and postoperative outcomes.

Patient demographics and comorbidities were collected from preoperative notes. The indication for surgery was classified as being secondary to chronic non-healing wound, trauma, or malignancy. Associated injuries to bone, nerve, and blood vessels along with the presence of underlying osteomyelitis were noted at the time of initial presentation. The soft tissue defect size along with the type of free flap procedure performed were obtained from operative notes. Wound complications within the immediate perioperative period were noted, including surgical site infection, dehiscence, seroma, hematoma, and delayed wound healing. Flap complications, including flap thrombosis and partial and complete flap loss were also evaluated. The development of new-onset osteomyelitis following definitive coverage was assessed within one year. Additional procedures directly related to the index free flap and performed within one year of the index

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operation were also recorded. Postoperative outcomes were assessed at one year. The primary outcomes included: flap success, definitive soft tissue coverage of the elbow, and elbow function. Elbow function was assessed from postoperative clinic notes commenting on elbow functional range of motion, where available. Range of motion was stratified as greater than 120 degrees of flexion and extension, 60-120 degrees of flexion and extension, and less than 60 degrees of flexion and extension. Descriptive statistical methods were used.

Results

A total of twenty-one patients underwent free flap reconstruction of soft tissue defects of the elbow. Demographic and clinical characteristics of the cohort are summarized in Table 1. The cohort was predominantly male [n = 14, (67%)] and Caucasian [n = 17, (76%)] with a mean age of 43 (range, 23 - 68). Indications for soft tissue coverage included: chronic non-healing wound [n = 5, (24%)], trauma [n = 12, (57%)], infection [n = 3, (14%)], and malignancy [n = 1, (5%)]. A total of 14 patients had concomitant bony injury (67%) associated with the index defect, and seven patients (33%) presented with preoperative osteomyelitis prior to soft tissue coverage. Seven patients (33%) were found to have nerve injury at the time of presentation, and one patient in the cohort had injury to the brachial artery following a motor vehicle collision that was repaired prior to reconstruction. Thirteen patients (62%) underwent delayed reconstruction. The mean time to free flap coverage in acute trauma patients was 4.3 days (range 0 – 63 days). One patient failed locoregional reconstruction prior to definitive free tissue transfer. The mean soft tissue defect size was 107.5 cm^2 (n = 14, range, 50 cm^2 – 250 cm^2). The types of free flaps utilized included: ALT [n = 15, (71%)], latissimus dorsi [n = 3, (14%)], TRAM [n = 1, (5%)], scapular [n = 1, (5%)], and parascapular [n = 1, (5%)]. All arterial anastomoses were made between the donor vessel and the brachial artery.

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Technical success was achieved in 100% of patients (n = 21). There were no partial or complete flap losses in the cohort. The following postoperative wound complications were reported: surgical site infection [n = 1, (5%)]; partial dehiscence [n = 5, (24%)]; seroma [n = 2, (10%)]; donor-site hematoma [n = 1, (5%)]; and delayed wound healing [n = 5, (24%)] (Table 2). One patient (5%) experienced flap venous thrombosis and underwent subsequent thrombectomy with eventual flap salvage. This patient underwent a parascapular flap for coverage of an open humeral fracture with significant soft tissue loss. In terms of additional flap-related reoperations, there were a total of 7 patients (33%) who underwent elective flap debulking. For delayed wound healing, 7 patients (33%) underwent irrigation/debridement following the index free flap, and 3 patients (14%) underwent flap elevation and re-insetting (Table 3).

At one year, flap success was 100% in the presented cohort. Following free flap coverage, zero patients developed new-onset osteomyelitis of the elbow. Further, all patients achieved definitive soft tissue coverage and successful limb salvage. Within one year of follow up, 17 patients had functional joint status available. Of these patients, eight (47%) had near-complete range of motion of the elbow (> 120 degrees flexion/extension), six (35%) had at least 60 to 120 degrees of combined elbow flexion/extension, while only three (18%) had significantly impaired joint mobility (Table 4). Of patients with near-complete regain of function, six initially presented with complex elbow trauma, and two presented with infection (one with septic joint and one with necrotizing fasciitis). Six of these patients underwent coverage with ALT and two underwent a free latissimus. Of patients with less than 60 degrees of flexion/extension, one presented with upper extremity sarcoma, one with chronic non-healing wound with associated osteomyelitis, and one with elbow fracture. These defects were reconstructed with free TRAM and ALT (x2) flaps,

respectively. Two of these patients had total joint fusion and one had significant stiffness limiting passive and active range of motion.

Case Reports

A first illustrative case is demonstrated in Figures 1 and 2. The patient was a 68-year-old female with a history of a chronically infected total elbow arthroplasty with exposed hardware necessitating free flap soft tissue coverage. The patient underwent a revision total elbow arthroplasty two years prior to the index free flap (Figure 1A) secondary to radial head malunion and periprosthetic ulnar fracture. This required an additional revision one year later, and then became infected with the patient noting skin breakdown with drainage overlying the implant, at which time she was evaluated by the microsurgical team. The patient subsequently underwent a free latissimus dorsi myocutaneous flap for coverage, which is shown immediately postoperatively in Figures 1B-1C. The postoperative course was uncomplicated, and the patient eventually achieved an adequate flap appearance after a debulking procedure six months postoperatively (Figure 1D). At one year postoperatively, the patient had regained a significant amount of elbow function compared to her baseline, as demonstrated in Video 1.

A second case is summarized in Figure 2. The patient was a 65-year-old female with a history of a synovial sarcoma of the left elbow, status-post resection and subsequent reconstruction with a total elbow replacement with an allograft composite ulna performed at an outside hospital 8 months prior to presentation for free flap coverage. The patient initially did well, but subsequently developed a chronically draining sinus tract requiring washout and coverage with a pedicled latissimus dorsi flap at an outside hospital. This eventually broke down, leaving an open wound of 50 cm^2. At this time, the patient presented to the senior authors for soft tissue coverage. Pre-operative radiographs are shown in Figure 2A. At this time, the elbow prosthesis was exposed,

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and it was subsequently removed, debrided, and replaced with an antibiotic spacer. When the total elbow replacement was re-implanted, a free ALT flap from the right thigh was used for reconstruction of the soft tissue envelope. The brachial artery was utilized for inflow, and the flap inset is demonstrated in Figure 2B. The postoperative course was uncomplicated, and the patient achieved durable soft tissue coverage of the joint, shown at six months postoperatively in Figure 2C. Eight months after this operation, she subsequently fractured her humerus proximal to the prosthesis and required a medial femoral consult vascularized bone graft to unite her humerus. This graft incorporated well, and the patient has continued to have durable soft tissue coverage and is undergoing physical therapy for elbow range of motion.

Discussion

The unique functional and anatomic characteristics of the elbow joint underlie the importance of adequate soft tissue coverage but concurrently make reconstruction of associated defects challenging. This retrospective case series aimed to explore the clinical and functional outcomes of microvascular free flap coverage for soft tissue defects of the elbow as there remains a paucity of literature examining patient outcomes of free flap coverage of the elbow. In the presented analysis of a large cohort of patients undergoing free flap coverage of the elbow, high rates of flap success, definitive soft tissue coverage, and limb salvage with a low incidence of flap complications was demonstrated. Functionally, the majority of patients (82%) recovered significant range of motion following reconstruction, with nearly half (47%) of the patients attaining over 120 degrees of elbow range of motion at one year.

In the presented analysis, performance of microvascular free flap coverage in coverage of soft tissue defects of the elbow was evaluated by assessing free flap failure, achievement of definite soft tissue coverage, and limb salvage. Zero patients faced flap failure in the present series, and all

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21 patients successfully achieved definitive soft tissue coverage and limb salvage at one year. This uniform clinical success was seen across a heterogeneous cohort of patients with soft tissue defects arising from acute trauma, chronic wounds, and malignancy. Further analysis of the impact of specific patient demographics, mechanism of injury, and treatment modalities was outside of the scope of the current report. Despite the fact that the elbow poses reconstructive challenges, the uniform clinical success demonstrated in the presented cohort is consistent with the current body of literature on free flap reconstruction of the elbow. Ooi et al. reported 100% flap success in a case series that included six free tissue transfers to the elbow (5 ALT flaps and 1 TRAM flap) (24). Chui et al. similarly demonstrated a 100% flap success rate in their study of 5 ALT free flap elbow coverage cases (22). Rayidi et al.'s study of 10 ALT flaps for elbow coverage demonstrated flap success and definitive coverage in 90% of the cases. The lone flap failure was a result of vascular dysfunction complicated by concomitant atherosclerosis (21). The presented data augment the prior limited literature on free flap coverage of elbow wounds, suggesting that flap success and limb salvage rates are high in situations where a free flap is warranted, such as in large posterior elbow wounds or where local reconstruction is not an option.

Safety was assessed by evaluating postoperative wound complications. In this cohort, there was a low incidence of immediate perioperative complications, including seroma, hematoma, flap thrombosis, and surgical site infections, consistent with prior series reporting on free flap coverage of elbow defects by Rayidi, et al. and Ooi, et al. (21,24). There was a comparatively higher incidence of wound breakdown in this cohort requiring debridement and re-closure; however, this did not ultimately impact long term flap success, definitive coverage, or functional outcomes. In general, recovery in the immediate perioperative period is challenging, as the nature of free flap reconstruction prohibits early weight-bearing on the joint. In many of the patients in this cohort,

protective external fixation was utilized postoperatively for flap elevation and protection; this technique has been described in additional reports on elbow free flap reconstruction, and likely contributed to the high rates of flap success in this series (25).

Finally, functional outcomes at one year were generally positive in this cohort. Among patients with potentially devastating traumatic injuries to the elbow joint or with limb-threatening infection, orthoplastic reconstruction utilizing free tissue transfer was associated with excellent attainment of not only limb salvage, but also highly functional elbow joints in the long term. Nearly half of the presented patients achieved near-complete range of motion at one year following reconstruction for a variety of indications, including elbow fracture, complex trauma, and acute infection. Both ALT and free latissimus flaps were utilized in these cases and were associated with positive functional outcomes. These flaps proved suitable for the eventual functional range of motion necessary for joint rehabilitation while concurrently providing durable soft-tissue coverage of the underlying joint space. Functional outcomes data for free flap coverage of the elbow remain limited in the literature and are relegated to small case series (24,25). This comparatively large cohort, though heterogeneous in defect size and indications for tissue transfer, suggests that attainment of acceptable elbow function following reconstruction is feasible in this patient population. However, in some patient populations functional prognosis remains dire despite successful soft tissue reconstruction with a free flap. For instance, in patients with an infected total elbow replacement, there is often an insufficient soft tissue envelope or an open wound over an exposed total elbow prosthesis. These patients often require a two-stage exchange, consisting of an antibiotic spacer followed by re-implantation of the elbow. Free flap reconstruction of the soft tissue envelope is vital prior to re-implantation of the joint; however, despite flap success, the risk of recurrent infection and functional limitations remain high in the population.

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Lessons Learned

In the fifteen years of experience of complex elbow coverage performed by the senior authors, there have been a multitude of lessons learned, primarily those that relate to inflow and flap selection. In the authors' experience, utilization of the brachial vessels enables more straightforward microsurgical anastomosis due to larger vessel caliber and a more favorable lie when performing the anastomosis. Proximal dissection to the brachial artery is generally found in a more reliable soft tissue plane, and antegrade end-to-side anastomosis can reliably be performed. In terms of flap selection, the senior authors' preference is to utilize free ALT flaps when possible due to reliable anatomy, ability to achieve primary closure of the donor site the majority of the time, and the degree of durable coverage available with this fasciocutaneous flap. Additionally, as the elbow is an anatomic region requiring thin, pliable coverage, debulking is almost always necessary. We perform these procedures at least twelve weeks from the index operation, and utilization of an ALT flap for coverage is again advantageous due to better ease of flap elevation for debulking compared to myocutaneous flaps. In our experience, ensuring durable soft tissue coverage early on enables a better ability to perform future revisions to improve functional outcomes. Even in patients with high BMI, we favor achieving stable coverage with fasciocutaneous flaps that can then be reliably de-bulked in the future. These advantages must be weighed against the downsides of utilizing fasciocutaneous flaps, including the potential for greater case difficulty, more complex pedicle dissection, and the potential for deficient pedicle length (in SCIP flaps, for example). In terms of immediate recovery, patients are typically immobilized for two weeks post-operatively from a flap perspective; however, concomitant orthopaedic procedures and joint stability may extend this timeframe and dictate timing to initiation of physical therapy. This report consists of patients with substantial soft tissue defects

necessitating free-tissue transfer, but for patients with smaller defects, we seek to first utilize locoregional flaps, most frequently pedicled radial forearm flaps.

Limitations

The presented case series has several limitations. Firstly, free flap reconstruction of elbow defects occurs infrequently such that even though all cases by two high volume microsurgeons were included as a complete cohort, the limited sample size prohibited any meaningful statistical analyses from being performed to effectively characterize risk factors for complications or factors associated with improved functional outcomes. Even so, to the authors' knowledge, this is the largest series reporting on free flap elbow reconstruction to date. Secondly, although the retrospective study design allowed for a unified collection of data from the 15-year experience of two surgeons in regard to parameters and outcomes measured, differences in surgical technique, procedural indications, defect sizes, and flap types were used between the two surgeons, which may explain the degree of variance in some of the presented data. Thirdly, since functional patient outcomes were determined retrospectively from postoperative clinic notes and only gathered when functional data was available at follow-up, the measurement of joint range of motion was not standardized across patients and may be susceptible to bias. Despite such limitations, the paper is able to achieve its aim to augment the sparse literature on free flap reconstruction of the elbow soft tissue envelope and convey the utility of such flaps in promoting long-term preservation of joint function and limb salvage.

Conclusion

In conclusion, microvascular free flap reconstruction is a safe and effective method of providing definitive soft tissue coverage of elbow defects, as evidenced by high rates of limb salvage and functional recovery following reconstruction.

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Figure Legends

Figure 1A: The patient was a 68-year-old female with a history of a chronically infected total elbow arthroplasty (TEA) with overlying soft tissue breakdown. Shown is the initial attempted revision TEA secondary to radial head malunion and ulnar periprosthetic fracture.

Figures 1B and 1C: Due to soft tissue breakdown over the revision TEA, the patient underwent free flap coverage of the elbow joint with a free latissimus dorsi myocutaneous flap. The flap is shown at one day postoperatively. The hospital course was uncomplicated.

Figure 1D: The patient underwent a flap debulking procedure six months following the index coverage procedure and achieved definitive soft tissue coverage with resolution of the underlying infection.

Video 1: Video demonstrating patient elbow function at one year postoperatively from free flap coverage. Despite a complicated course of a persistently infected prosthetic elbow joint, free flap coverage enabled the underlying infection to resolve, to achieve definitive soft tissue coverage, and to permit functional range of motion at one year.

Figure 2A: The patient was a 65-year-old female with a history of synovial carcinoma of the left elbow. This was resected, and the elbow was reconstructed with a total elbow replacement. The patient initially did well, but subsequently developed a chronically draining sinus tract requiring washout and coverage with a pedicled latissimus dorsi flap, which broke down, leaving an open

wound. Shown, is this patient's pre-operative radiographs at the time of presentation to the senior authors for free tissue transfer.

Figure 2B: The patient underwent an anterolateral thigh (ALT) flap for coverage of the elbow. Shown is the patient in the operating room following flap inset. The brachial artery was used for inflow, and anastomosis was performed in an end-to-side fashion.

Figure 2C: The patient achieved durable soft tissue coverage of the elbow, facilitating further orthopaedic procedures for joint reconstruction and rehabilitation. Shown, is the patient at six months post-operatively.

Table 1. Demographic and clinical characteristics of the patients.

Characteristic	**Value (n = 21)**
Demographic	
Age (years), mean (range)	43 (23, 68)
Female	7 (33%)
Male	14 (67%)
Race or ethnic group	
Caucasian/White	16 (76%)
African American/Black	2 (10%)
Non-Hispanic/Latino	21 (100%)
Other	3 (14%)
Clinical	
BMI (kg/m^2), mean (range)	27.0 (19.9, 38.7)
Comorbidities	
Hypertension	6 (29%)
Diabetes Mellitus	2 (10%)
Peripheral Vascular Disease	0 (0%)
Chronic Kidney Disease	1 (5%)
Hyperlipidemia	4 (19%)
Indication for Soft Tissue Coverage	

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Chronic, non-healing wound	5 (24%)
Trauma	12 (57%)
Malignancy	1 (5%)
Infection	3 (14%)
Index defect	
Bony injury present	14 (67%)
Pre-operative osteomyelitis	7 (33%)
*Defect size (cm^2), mean (range)**	107.5 (50.0, 250.0)
Type of Free Flap	
ALT	15 (71%)
Latissimus dorsi	3 (14%)
TRAM	1 (5%)
Scapular	1 (5%)
Parascapular	1 (5%)

Note – data are presented as frequencies and percentages unless otherwise noted. BMI = body mass index; ALT = anterolateral thigh flap; TRAM = transversus rectus abdominis myocutaneous flap
* n = 14 for defect size

Table 2. Perioperative flap and donor-site complications.

Complication	**Incidence (n= 21)**
Surgical site infection	1 (5%)
Partial dehiscence (flap)	5 (24%)
Seroma	2 (10%)
Donor-site hematoma	1 (5%)
Flap thrombosis	1 (5%)
Partial flap failure	0 (0%)
Complete flap failure	0 (0%)
Delayed wound healing	5 (24%)

Note – Data are presented as frequencies and percentages

Table 3. Reoperations within one-year post-free tissue transfer.

Procedure	**Number of patients (n = 21)**	**Number of procedures**

Non-elective		
I&D (donor or recipient site)	7 (33%)	11
Flap elevation and re-insetting	3 (14%)	3
Thrombectomy	1 (5%)	1
Elective		
Flap debulking	7 (33%)	7
Flap augmentation	1 (5%)	1
STSG/Integra placement	2 (10%)	2
Note – Data are presented as frequencies and percentages. I&D = irrigation and debridement; STSG = split-thickness skin graft		

Table 4. Surgical and functional outcomes following free tissue transfer.

Outcome	**Number of patients (n = 21)**
Flap success	21 (100%)
Definitive soft tissue coverage	21 (100%)
Limb salvage	21 (100%)
New-onset osteomyelitis	0 (0%)
Elbow function at one year*	
> 120 degrees combined flexion/extension	8 (47%)
60-120 degrees combined flexion/extension	6 (35%)
< 60 degrees combined flexion/extension	3 (18%)
Note – data are presented as frequencies and percentages. * Range of motion relative to neutral position	

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