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## Article

# Optimizing Outcomes in Mangled Lower Extremity Reconstruction: Insights from a Retrospective Study of 93 Patients and Their Functional Scores

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**Abstract: Introduction:** Over the past 25 years, advancements in reconstructive techniques and patient management have significantly improved outcomes in mangled lower extremity injuries. Functional results of limb salvage have been demonstrated to surpass those of primary amputations. Developments such as the use of local fasciocutaneous flaps, vacuum-assisted closure, and hyperbaric oxygen therapy have enhanced the reconstructive ladder. Despite progress, the utility of the Mangled Extremity Severity Score (MESS) and Gustilo-Anderson classification remains debated, particularly in their prognostic value for limb salvage decisions. **Materials and Methods:** This retrospective study analyzed 93 patients treated for mangled lower extremities between January 2015 and October 2022. Patients were assessed for age, gender, injury location, MESS scores, Gustilo-Anderson classifications, surgical methods, and functional outcomes using the Lower Extremity Functional Scale (LEFS). Surgical interventions included internal and external fixation, skin grafts, local flaps, muscle flaps, and free tissue transfer. LEFS scores were categorized into disability levels for functional evaluation. Correlations were drawn between LEFS and variables such as MESS, Gustilo-Anderson types, and nerve injuries. **Results:** Among the 93 patients, 16 had MESS  $\geq 7$ , and 77 had MESS  $< 7$ . Reconstruction methods included local fasciocutaneous and muscle flaps (37 patients), free tissue transfer (29 patients), and skin grafting with vacuum-assisted closure (27 patients). Smoking was associated with delayed union and increased infection rates. LEFS scores were significantly lower in patients with MESS  $\geq 7$ , Gustilo grade 3C fractures, and tibial nerve injuries. Flap failures and higher numbers of surgeries ( $>3$ ) also correlated with poorer functional outcomes. Average soft tissue healing time was 18 days, and bone union time was 17 weeks. **Discussion:** Lower extremity reconstruction demands precise surgical planning and execution, prioritizing functional restoration. MESS and Gustilo-Anderson classifications provide useful frameworks but have limitations in predicting long-term functionality. Factors such as joint involvement, nerve injuries, and flap selection significantly influence outcomes. Smoking and delayed healing remain critical challenges. While free flaps are essential for complex defects, simpler methods yield better outcomes in suitable cases. LEFS emerged as a reliable tool.

**Keywords:** lower extremity injury; reconstruction; MESS; Gustilo-Anderson; LEFS

## Introduction

In the last 25 years, much has changed in mangled lower extremity reconstruction, patient assessment, and treatment methods. The oldest and most important question about the subject has been answered. It has shown that definite functional results of limb salvage are superior to one of the primary amputations from many aspects [1]. Traumatic soft tissue defects were once deemed dependent on free flaps, later on successful treatment was achieved by local fasciocutaneous flaps with the determination of new axial patterns of flap techniques [2–4]. Furthermore relatively new methods are facilitating dressing changes like vacuum-assisted closure and hyperbaric oxygen treatment appear to be supportive factors of reconstructive ladder in this form of injury [5,6].

Classifications on extremity trauma with mangled extremity severity score (MESS) are used as a “debatable” answer for the main question “extremity is salvageable or not?” [7]. Categorizing the open fractures (Gustilo-Anderson Classification) led us to give a prognostic framework and treatment algorithm for bone and soft tissue injury also infection protection [8,9]. Surgical intervention is tailored with the data; usage of antibiotics and fixation choices of bone and soft tissue reconstructive options are planned.

In this study, we focus on the result of the lower extremity functional scale (LEFS) and its relationship with MESS, Gustilo-Anderson classification and anatomic characteristics of injuries by reconstructing 93 patients.

## Material and Method

This study was conducted around the heavily industrialized zone with dense traffic flow. One hundred fifteen patients admitted to our clinic between January 2015 and October 2022 have undergone either salvage operations, lower extremity reconstruction or amputation according to their initial MESS at admission. The main trauma reasons are motor vehicle accidents and work accidents. Ninety three patients were included in the salvage group, and 22 had amputations. Injury of 22 patients has resulted in limb amputation due to the severe derangement of neurovascular structures, catastrophic soft tissue injury, and additional life-threatening trauma. (primary amputations performed in ten cases and secondary amputations performed in twelve cases).

Data from total of 93 patients is collected. These patients have been assessed by their gender, age, location of the injury, MESS at admission, Gustilo-Anderson classification, performed reconstructive method, total count of operations performed, motor or sensational nerve dysfunction, and LEFS.

Our study was conducted by the Declaration of Helsinki. Verbal consent was obtained from all patients for this study. 70 male and 23 female individuals were included in our study.

*A-Age:* Age distribution is 5 to 78 years, with an average of 34 years. Patients were divided into two groups, over 50 years old and under 50 years. Seven patients were younger than 18 years.

*B-Location of injury:* The injury site is the leg and ankle region; therefore, patients suffered tibia-fibula and ankle region fractures.

*C-Mangled extremity severity score:* MESS was evaluated at initial admission [10]. Patients were divided into two main groups. Scores are seven or above ( $\geq 7$ ) and less than seven ( $<7$ ). All patients suffered an open fracture.

*D-The Gustilo-Anderson classification:* All patients have open fractures and Gustilo-Anderson classification is used for the treatment algorithm [11,12].

*E- Performed reconstructive soft tissue and bone fixation method:* Operative procedures are managed by orthopedic and plastic surgeons. Data on bone procedures and soft tissue reconstruction types have been collected. Soft tissue reconstructions consist of skin grafts, local fasciocutaneous flaps, muscle flaps, or free tissue transfer. Orthopedic treatment was internal and/or external fixation. Internal fixation of plate or intramedullary nails is mainly reserved for Type 1-2 Gustilo-Anderson fractures, and external fixation is for Type 3 fractures.

Considering these data, the underlying algorithm and principles dealing with these types of injuries have been aimed to be determined.

Twentynine patients have undergone free tissue transfer, 37 patients have local fasciocutaneous and muscle flap operations, and 27 patients reconstruction via split-thickness skin graft and vacuum-assisted closure. In free tissue transfer operations, the recipient's vessel has been anastomosed in an end to end fashion to anterior or posterior tibial arteries and in an end to side manner to the popliteal artery. Reconstruction with latissimus dorsi free muscle flap operation has been performed in 12 patients, osteocutaneous fibula free flap in 8 patients, rectus abdominis free muscle flap in 3 patients, radial forearm free flap in 3 patients, and anterolateral thigh free flap in 3 patients. Total flap necrosis has occurred in 3 patients and partial flap necrosis in 4 patients. Reconstruction of these limbs has been achieved via vacuum-assisted closure and skin grafting. Wound site infection has been observed in 12 patients, and regression occurred following proper intravenous antibiotic treatment.

*F-Total counts of operations:* Total count of repetitive operations for each patient is documented. Patients were divided into those with more than three operations and those with three or fewer operations.

*G- Motor or sensational nerve dysfunction:* Tibial and peroneal nerve patency were examined at initial admission. An electromyography (EMG) study was performed whom with motor nerve dysfunction were detected when the extremity was suitable.

*H-Lower extremity functional scale at last follow-up:* After successful soft tissue coverage and bone union, functional scores were assessed by LEFS [13–15]. The patients were categorized into five groups of disability based on their percentage of maximal function ( $LEFS/80 \times 100$ ): Bedbound - 0% to 20% score, crippled - 20% to 40% score, severe disability - 40% to 60% score, moderate disability - 60% to 80% score, minimal disability - 80% to 100% score).

The summary of patient data is presented in the table.

**Table.** Summary of Patients Data on Mangled Lower Extremities.

Category	Subcategory	Number of Patients
Mangled Extremity Severity Score (MESS)	2	25
	3	13
	4	21
	5	12
	6	6
	7	4
	8	6
	9	4
	10	2
Gustillo Classification	I	24
	II	30
	III A	16
	III B	19

	III C	4
Soft Tissue Reconstruction	Skin graft and/or VAC	27
	Local Flaps	37
	Free Flaps	29
Orthopedic Procedures	Cast	17
	Intramedullary nail and plate	38
	External fixators	16
	Both	22
Functional Scores	Bedbound	0
	Crippled	2
	Severe disability	7
	Moderate disability	17
	Minimal disability	66

## Results

The study was carried out by collecting retrospective data. The mean follow-up period is 22 months (8 to 35 months).

*Healing:* The average healing time of soft tissues is about 18 days, and the average bone union time is 17 weeks.

*A-Age:* 11 patients are over 50, and 82 patients are below 50

*B-Location of injury:* 20 patients (22%) of the injuries were in the proximal one-third including knee, 28 patients (30%) in the middle one-third, and 45 (48%) in the distal one-third including the ankle. Eleven patients of the proximal and distal one third group have an intraarticular fracture of the knee (2 case) and ankle (9 case) joint.

*C-Mangled extremity severity score: The MESS results:* Scores are seven or above ( $\geq 7$ ) in 16 patients and less than seven ( $<7$ ) in 77 patients.

*D-The Gustilo-Anderson classification:* 24 patients grade one, 30 patients grade two, and 39 patients have grade three fractures.

*E- Performed soft tissue reconstructive and bone fixation methods:* Soft tissue coverage protocols are divided by assessing local or distant flap requirements. The operative procedure is executed in the first 72 hours when free tissue is transferred and planned early after emergency service admission.

In case of flap failure initially, skin grafting combined with vacuum-assisted closure is preferred [5]. Local flap options and skin grafting have been preferred primarily in elderly patients with comorbid diseases. When the condition of recipient vascular structures with already existing vascular pathologies such as arteriosclerosis, free tissue transfer does not perform.

Defects of distal one-third of the lower extremity free tissue transfer procedures were performed. For proximal and middle third defects, gastrocnemius and soleus muscle flaps, transposition flaps, and bipedicle fasciocutaneous flaps have been preferred. Three patients with bone defects in the middle third have undergone reconstruction with ipsilateral fibula osteocutaneous flap.



*F-Total counts of operations:* 69 patients have three or less surgeries; 24 have more than three surgeries. High-energy open tibia fractures required an average of 8.5 months to heal.

*G- Motor or sensorineural dysfunction:* 6 Patients had motor nerve injury, 4 in the tibial and 2 in the peroneal nerve. That patients overall scores were poor.

*H-Lower extremity functional scale, at last follows up:* The correlation of LEFS with, bone healing time, and free flap requirements was mainly insignificant. The correlation of LEFS with MESS, permanent motor nerve dysfunction, and Gustilo-Andersen fracture types and intra-articular fractures is worth mentioning.

Smoking was associated with an increased risk of delayed union, with revision surgery being needed in %59.1 of smokers compared to 40.6 % of nonsmokers. Rates of infection were high at %30.3. Smoking was associated with an increased risk of infection (%60.4 vs. %39.6).

## Discussion

Open fractures of the tibia are the most common open long bone fractures, with an annual incidence of 3.4 per 100 000 [16,17]. The mean age of those who sustain open tibial fractures is 43.3 years, most frequently occurring in young adult males and elderly females [18]. High-energy trauma is the primary mechanism of injury, with over 50% of cases being attributed to road traffic accidents or falls from a great height [16–19]. Noteworthy, the vast majority of proximal and distal tibial fractures present with a significant soft-tissue injury and therefore pose additional complexity when managing the injury. Primary amputation may be considered in uncontrollable hemorrhage, prolonged crush injury, an avascular limb, or segmental bone/muscle loss. The decision is not taken lightly and should be discussed with other experienced surgeons [20–22]. Severity scores may provide a measured value in predicting the need for amputation [23,24].

Secondary amputation may also be a viable surgical option in an injury complicated by ongoing problems, e.g., deep infection. Amputation is an indicator of poor outcome [20]. But may be necessary for preventing further deterioration or maintaining the quality of life. Long-term functional results may not be significantly affected in the amputee when compared with that which would have occurred in a salvaged injury.

Open fracture management requires careful assessment of the bone injury, including fracture characteristics and bone loss, as well as soft tissues, including contamination, integument injury, muscle damage, and neurovascular injury. The Gustilo-Anderson classification and MESS remain the most utilized classification systems for open fractures.

Managing severely traumatized limbs is challenging for orthopedic and plastic surgeons. The main aim here is not to salvage the limb but also to give the patient a sensate, functional limb. Existing scoring methods to help decide whether to amputate or reconstruct the limb are considered inadequate [2]. Current literature focuses on surgical salvage of the limb rather than outcomes. Patients are deliberately dissatisfied when this demanding treatment ends with poorly functioning extremities. Is there a predictable value of salvaged limb that is functionally stable in daily life and work?

Over the past three decades, lower extremity amputation rates have gradually declined thanks to the development of microsurgical techniques and devices. Functional reconstruction of the lower extremity is now possible [3]. The goals of open fracture management include decreasing infection risk and promoting fracture union.

Fractures of bony structures and injuries to neural and vascular structures often complicate severe lower extremity injuries [3]. The vascular injuries that threaten the viability of the limb should be treated beforehand [2]. Depending on the nature of the defect, the most appropriate reconstruction procedure was chosen, and successful reconstruction results were achieved. Simple local flaps and skin grafts were the treatment modalities for children. Additional donor site morbidity may lead to functional impairment in future years. While vacuum-assisted closure and skin grafting are the reconstruction methods of choice for fundamental tissue defects, free tissue transfer is the gold standard for reconstructing composite tissue defects [3,4,25,26].

Gustilo-Anderson Grade 3C fractures and some Grade 2B fractures in elderly patients are challenging to manage [9,12]. Problems with soft tissue coverage are directly related to the process of bone union. Good periosteal coverage is a prerequisite for bone healing. Delayed healing and non-healing correlate strongly with soft tissue problems.

MESS was a shining star in evaluating the mangled extremities [8]. But in the last decade, the deficits about MESS have become prominent, and reliability is damaged. The positive and negative value of prediction is emphasized [7].

Ankle and knee motion is critical to our series. Achieving a stable and pain-free joints in tibial fractures is of utmost importance to patient satisfaction [27]. Therefore, every attempt should be made to restore joint congruency of the ankle and knee [28].

Motor nerve status is an essential aspect of the function, but the loss of sensibility of the plantar area also significantly impacts functions [29]. So, every attempt to preserve the integrity of the tibial nerve than the peroneal nerve is attempted. The functional outcomes of patients who underwent nerve repair were significantly worse than those who did not. In addition, it was observed that the functional scores of patients with three or more surgeries were negatively affected.

LEFS is a reliable and patient-centered assessment tool that reflects patients conditions from their perspective [30,31]. No outside intervention or medical device is required. Patients are highly oriented and satisfied with the final scale of LEFS. Recent functional studies between the amputee and salvaged patients have shown that amputee patients have higher functional scores, lower pain scores, and earlier return to daily life and work [32]. LEFS scores are strongly correlated with MESS over 7, Gustilo grade 3 C fracture, free tissue transfer, fractures involving the ankle, and tibial nerve injuries. The functional scores are strongly related to the MESS and Gustillo Andersen types. These results suggest that free flaps used in delayed union groups and groups have poorer LEFS scores, whereas local flaps and regular union groups have good LEFS scores overall [33]. Three patients underwent repair for osteomyelitis of the tibia and developing nonunion with an ipsilateral fibular bone flap. When the final values of these patients were examined, they were found to have terrible overall values.

All type 3C patients underwent revascularization. In 4 patients, the injury was repaired at the level of the posterior tibial artery. The reason for this was that these patients also had nerve injuries in addition to vascular injuries. While 6 of these patients underwent immediate restoration, one underwent secondary repair with a sural nerve graft. The final score of patients who underwent nerve repair was less than 7.

Free tissue transfer was performed in all patients with type 3 C and type 3 B these patients was, on average, eight days longer than in the other remaining cases, no significant change in final scores was observed.

So, we will create a "prediction scale" that salvaged limbs will be functional or non-functional [34]. Then we inform the patient during the course that the efforts will have resulted in poor function even when compared with amputee patients.

## Conclusion

Reconstruction of extensive lower extremity injuries requires the utmost theoretic knowledge and technical skill in plastic and orthopedic surgery. Successful reconstructions in these cases require the choice of the most appropriate treatment modality for the patient and flawless execution of the procedure.

Functional score, complications of bony union, and healing time are closely related to the adequacy of treatment to cover the soft tissue. Shorter healing time and higher functional scores are better in the group of patients with less than 7 in MESS and lower Gustilo-Anderson scales.

**Conflicts of Interests:** No competing of interests.

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**Ethical approval:** The ethical approval of the study was obtained from the Anadolu Medical Center Clinical Research Ethics Committee (Decision Number: ASM-EK-23 / 215).

## Abbreviations

The following abbreviations are used in this manuscript:

MESS	Mangled Extremity Severity Score
LEFS	Lower Extremity Functional Scale
EMG	Electromyography

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