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Evaluation of Complicated Lower Extremity Injuries Requiring Soft Tissue Reconstruction

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Abstract: Reconstruction of tissue defects in the distal lower extremities is challenging. The issue is further complicated when problems such as high-impact traumas, firearm injuries, and age-related arteriosclerosis are added to these factors. Patients who presented with open fracture of the lower extremity and underwent soft tissue reconstruction were analyzed The patients were evaluated in terms of age, sex, mechanism of trauma, wound coverage time, bone repair techniques, soft tissue repair techniques. Statistically, the time from initial injury to surgical reconstruction was compared according to location of injury, age, etiology stabilization technique. There were no statistically significant difference between the time from initial injury to surgical reconstructions according to the age, etiologies and stabilization technique; but distal region and bacterial contamination were found to have longer time from initial injury to surgical. Eleven patients (61.2%) underwent reconstruction using muscle flap. Not only the factors like the bacterial growth but also the level of the injury is also affected the time from initial injury to late surgical reconstruction. Cross-leg flaps can be used in selected patients to spare the extremity in patients with severe soft tissue and bone damage due to firearm injury, especially buckshot, when the recipient vessels are problematic.

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INTRODUCTION

Reconstruction of tissue defects in the distal lower extremities is challenging due to the insufficiency of adjacent tissues compared to other areas of the limb[1]. The issue is further complicated when problems such as high-impact traumas, firearm injuries, and age-related arteriosclerosis are added to these anatomic factors. The accepted approach is to cover the fracture line and exposed bone fragments with a tissue that has a good blood supply as soon as possible. However, this cannot always be achieved. Severely infected wounds, soft tissue wounds and infections associated with high-impact injuries, and plate and screw exposures can make this approach impossible to execute. Especially in firearm and avulsion-type injuries, the healing process may be prolonged and long-term wound dressing and broad-spectrum antibiotic therapy may be necessary to fight infection. Options for reconstruction include many fasciocutaneous and muscle flap methods[2], while bone fixation can be achieved by internal or external fixation methods[3].

Although free flap options for reconstruction provide the tissue required for defect repair, vessels that have been damaged by trauma or are arteriosclerotic both pose problems. Plate exposure transforms closed fractures to open fractures, which can involve a long and difficult treatment process in the elderly patient population.

The purpose of this study is to introduce the our treatment protocol for the complicated lower extremity injuries and find the affect of age, stabilization technique, level of injury and etiology to the soft tissue time from initial injury to surgical reconstruction.

MATERIALS and METHODS

Patients who presented with open fracture of the lower extremity and underwent soft tissue reconstruction in our center between 2014 and 2020 were analyzed. The patients were evaluated in terms of age, sex, mechanism of trauma, wound coverage time, bone repair techniques, soft tissue repair techniques, bacterial growth, and complications. Ethics committee approval for the study was obtained from the local ethics committee of Sivas Cumhuriyet University. (No:2020-03/21)

For the statistical analysis; stabilization type was divided as external fixation and internal fixation. External fixation and split were accepted as external fixation whereas intramedullary screw, K-wire, plate and screw stabilization techniques were accepted internal fixation. Also etiological parameters were divided as firearm injury and others. The location of the injury was divided proximal and distal. Proximal region was counted in 1/3 central and upper portion of leg, while distal region was counted in 1/3 lower and upper portion of leg and foot. Statistically, the time from initial injury to surgical reconstruction was compared according to location of injury, age, etiology stabilization technique.

After hospital admission, all patients received empirical antibiotherapy and underwent irrigation. Tissue samples were obtained from each patient for culture; swab samples were not used to identify infectious agents. Patients were followed up with daily dressing and antibiotherapy started according to the culture result. Reconstruction was planned when sufficient granulation tissue was obtained in wounds.

Statistical evaluations

Number Cruncher Statistical System 2007 (Kaysville, Utah, USA)) program was used for the statistical analyses. In addition to descriptive statistical methods (mean, standard deviation, median frequency, ratio, minimum and maximum) were used. The suitability of the quantitative data of normal distribution was tested by Kolmogorov-Smirnov, Shapiro-Wilk test and graphical evaluations. Mann Whitney U test was used to compare two groups which has not normally distributed data. Significance was evaluated at the level of $p<0.05$.

RESULTS

A total of 18 patients were identified in the screening. All of the patients were men. Etiology of the trauma was firearm injury in 6 patients (33.4%), traffic accident in 9 patients (50%), fall from a height in 2 patients (11.1%), and occupational accident in 1 patient (5.5%). Four patients underwent reconstruction due to plate and screw exposure. Trauma was due to fall in 2 of these patients and traffic accident in the other 2 patients. In one of these patients, the soft tissue defect occurred as a result of plate and screw installation, and a muscle flap was used. Additional morbidity was detected in 38.9% (n = 7) of the cases. The additional morbidities were diabetes mellitus (5), atherosclerotic heart disease(3), hypertension(4).

The mean age of the patients was 49.94±22.51 (age: 18–86) years while 50.0% of the patients (n = 9) were under 50 years old and 50.0% of them (n = 9) were over 50 years old. Eleven patients (61.1%) had tibia and fibula fracture, 2 (11.1%) had tibia fracture alone, 1 (5.5%) had fibula fracture alone, and the other 4 patients (22.2%) had fractures of the foot bones. The bones were stabilized using external fixation in 6 patients (33.4%), intramedullary screw in 4 patients (22.2%), K-wire stabilization in 5 patients (27.7%), and plate and screw stabilization in 1 patient (5.5%). A splint was applied to 2 patients (11.1%). The mean time from open fracture to soft tissue reconstruction was 25.50±19.75 and median 21.5 day . This delay was caused by a 43-year-old patient injured in an intravehicular motor vehicle accident who initially refused surgery but presented again later, and surgery was also delayed in other patients due to infection (Table 1 and 2).

Tissue biopsy cultures were performed for all patients and the results were negative in 6 patients. Of the other 12 patients, a single agent was detected in 5 patients and multiple agents were isolated from the remaining 7 patients. Gram-negative bacteria were most commonly isolated (n=12, 63.15%) and the most common gram-negative bacteria were Acinetobacter Baumanni (n=4, 21.05%). Gram-positive bacteria was isolated (n=5, 26.31%) and the most common gram-positive bacteria were Corynebacterium spp. (n=5, 26.3%) Agents isolated from our patients are shown in Table 1.

When the data are statistically analyzed, there was no statistically significant difference between the time from initial injury to surgical reconstructions according to the age of the cases ($p> 0.05$). According to etiologies, stabilization technique and the additional morbidity; the time from initial injury to surgical reconstructions of the cases did not show statistically significant difference ($p> 0.05$). According to localizations of the injury ($p=0.012$; $p <0.05$) and bacterial reproduction the injury area ($p=0.032$; $p <0.05$); there were statistically significant difference between the time from initial injury to surgical reconstructions of the cases; those in the distal region and bacterial growth wounds were found to have longer time from initial injury to surgical reconstructions than those in the own groups (Table 3).

Four patients (22.2%) received a split-thickness skin graft after adequate granulation, while fasciocutaneous flaps were used in 2 patients (11.1%). Eleven patients (61.2%) underwent reconstruction using muscle flap. Transverse gastrocnemius muscle flap was used in 2 patients with severe soft tissue and bone damage in the ankle due to firearm injury (Figure1,2). One of these patients had a previous rectus abdominis free flap that was lost to infection on the third postoperative day. Exploration of the flap revealed thrombus and infection, and passage of the thrombus into the recipient vessel prevented the restoration of blood flow in the vessel after revision. A transverse leg flap was applied in the other patient due to a recipient artery problem and high anesthesia risk associated with comorbidities. Free flaps were applied in only 2 patients; the other patients' reconstructions were done with pedicled soleus and gastrocnemius muscle flaps. Soleus flaps were applied in a total of 6 patients. Of these, 3 were superiorly pedicled and 3 were inferiorly pedicled flaps (Figure 3). Gastrocnemius flap was applied to 4 patients in total and rectus abdominis flap was applied to 2 patients. Muscle flaps were covered with split-thickness skin grafts.

Figure 1. 69 years old male patient who had soft tissue and bone defect because of the firearm injury. Aterosclerosis was detected all of the upper ekstremity recipient vessels. Reconstruction was done with cross gastrocnemius muscle flap and skin .Postoperative 2,5 months photography

Figure 2. 54 years old male patient who had soft tissue and bone defect because of the firearm injury. Free latissmus dorsi flap was lost because of recipient vessel failure and infection. Reconstruction was done with cross gastrocnemius muscle flap and skin .Postoperative 12 months photography

Figure 3. 84 years old male patient who had soft tissue defect because of plate exposition after plate removed. Reconstruction was done with distal soleus muscle flap and skin graft. Postoperative 8 months photography

The patient who underwent grafting of the dorsum of the foot was lost to follow-up because he lived in a different city. The mean follow-up time of the remaining 17 patients was 15.3 months. Other than focal graft loss, patients experienced no additional complications in the final reconstructions.

DISCUSSION

The thinness of the soft tissue related to the tibia, especially on the anterior side, makes this bone vulnerable to injury, and the limited soft tissue cover makes reconstruction completely unfeasible. Depending on the nature of the trauma, soft tissue defects that occur in addition to fracture make it even more difficult due to various factors such as osteomyelitis, tissue necrosis, bone necrosis, and most importantly, infection of the soft tissue itself. Performing soft tissue repairs within the first 72 hours of open fracture is said to reduce the risk of infection and flap complications[4,5]. However, this is usually not possible in complicated and contaminated injuries caused by firearms. The blast effect due to injury causes soft tissue defects as well as severe bone defects and results in severe sequelae, particularly in joints. At the statistical analysis in our series, it was observed that there wasn't significant difference at the soft tissue time from initial injury to surgical reconstruction between firearm injury and other causes of injuries.

Moreover, large bone defects lead to shortening of the extremities. Although grafting is performed in such cases, achieving an infection-free environment with good blood supply plays a key role in graft success. Another major issue in open fractures is injury of the soft tissue surrounding the bone, particularly the periosteum. Injuries in these tissues adversely impact bone healing[6,7]. Although growth in the wound area is observed when patients with plate and screw exposure present to the hospital, incision and debridement performed on these patients to remove the plate and screw lead to more extensive defects than expected. Infection in these patients results in prolonged wound closure time.

The nature of firearm injuries and crush or avulsion injuries make them especially prone to infection, and these infectious conditions increase tissue necrosis, causing enlargement of the defect and greater bone loss. Moreover, in such injuries it is not always possible to distinguish viable tissues from dead tissues in the early stage of injury. External fixators are preferable for early bone fixation because they do not cause further injury to traumatized bone, they disrupt bone circulation less than more invasive methods, and they facilitate effective wound dressing, although external fixators that remain longer than 28 days increase the risk of infection[8-10]. In addition, it was reported that removing pins because the external fixator obstructs soft tissue reconstruction disturbs the reduction, disrupts the structure of forming callus tissue, and can lead to delayed union, nonunion, and malunion[1]. Intramedullary screwing further disrupts healing of the fracture by damaging the bone circulation and can increase complications in open fractures, although it has been successfully used with flap application in severe tibial fractures. However, plate and screw fixation is not recommended due to high complication rates 3,10. In our series we determined that the soft tissue time from initial injury to surgical reconstruction is not associated with stabilization technique. The bone stabilization technique may not affect soft tissue healing and may be associated with complications related to long-term bone healing. We preferred external fixators in dirty and defective injuries in which early soft tissue reconstruction could not be performed, such as firearm injuries and plate exposure. We believe that this provided more effective wound care, as we avoided spreading infection to the upper bone segments with invasive procedures and were able to perform the necessary debridement without disrupting the reduction with external fixators.

Other than timing, other important factors in reconstruction planning are the presence of infection, defect size, degree of soft tissue damage[11,12]. In the series; distal portion of the lower extremity injuries had longer time from initial injury to surgical reconstructions than those in the proximal portions. Therefore not only the factors like the bacterial status of the wound, type of fracture, different types of tissues involved in the injury, and the exposed structures[13] but also the level of the injury is also affected the time from initial injury to surgical reconstruction.

Infections prolong the time required for soft tissue reconstruction as well as lead to necrosis, enlargement of the defect, and impaired bone healing. Studies have reported that 60–70% of patients with open fracture injuries have positive wound cultures prior to receiving treatment in the hospital[14,15]. Moreover, it was reported that the infection rate is strongly correlated with the degree of open fracture rather than the initial surgical intervention[16]. In our series, 2 patients aged 54 and 69 who sustained firearm injury with defects of the ankle required extensive interventions due to infection and even had flap loss, which we also attributed to infection. In the literature, it was reported that gram-negative and gram-positive bacteria were isolated in 44.3% and 42.4% of the patients, respectively[3]. In contrast, we isolated gram-negative bacteria in 63.15 %of our small series. All isolates were obtained from tissue culture.

Generally accepted reconstruction methods are fasciocutaneous and muscle flaps, and local or free flap options can also be used. However, certain clinics have reported using flap options less often, favoring the use of skin grafts following vacuum-assisted closure[12]. Muscle flaps with good blood supply and muscle tissue were shown to be superior to fasciocutaneous tissues in the healing of open tibial fractures[17]. Particularly for wounds that are infected or have high risk of infection, muscle flaps seem to be a better option in terms of bone healing and resistance to infection. In many cases with small periosteum injury, appropriate antibiotherapy and vacuum-assisted closure methods provide sufficient granulation tissue for graft application and assist in the prevention of donor site morbidity caused by the flap. Although free flaps are still the gold standard for large defects and patients that require a large volume of tissue, they may not be useful when cases of severe trauma causing recipient vessel problems are complicated by arteriosclerosis. It must also be kept in mind that in buckshot or birdshot wounds, there is injury to the surrounding tissues in addition to the visible defect due to shot spread.

Table 1: Demographic data and other patient characteristics including localization, etiology, microbiological agents and reconstructive techniques of wounds

	Years	Time from Initial Injury to Surgical Reconstructions (day)	Etiology	Soft tissue Defect Localization	Microbiological Agent	Soft tissue Defect reconstruction technique	Fracture localization	Fixation technique
1	18	14	firearm injury	cruris 1/3 middle	None	Soleus muscle flap with superior pedicle and skin graft	Fibula and tibia body	Intramedullary screw
2	37	6	firearm injury	cruris 1/3 middle	Acinetobacter Baumannii, Enterecoccus	Soleus muscle flap with superior pedicle and skin graft	Fibula and tibia body	External fixator
3	69	22	firearm injury	ankle	Acinetobacter Baumannii, Corynbacterium Striatum	Cross gastrocnemius muscle flap and skin graft	Distal fibula and tibia	External fixator
4	54	75	firearm injury	ankle	Corynbacterium Striatum, Statylococ-cusHaemolytıcus	Cross gastrocnemius muscle flap and skin graft	Distal fibula and tibia	External fixator
5	57	10	firearm injury	cruris 1/3 superior	None	Gastrocnemius muscle flap and skin graft	Proksimal tibia	External fixator
6	28	9	traffic accident	cruris 1/3 middle	None	Soleus muscle flap with superior pedicle and skin graft	Tibia and fibula body	Intramedullary screw
7	84	12	Plate exposition	cruris 1/3 inferior	Acinetobacter Baumannii	Hemisolues muscle flap with inferior pedicle and skin graft	distal tibia and fibula	External fixator
8	79	21	Plate exposition	cruris 1/3 inferior	Corynbacterium Species	Hemisolues muscle flap with inferior pedicle and skin graft	Distal tibia and fibula	K wire
9	86	28	Plate exposition	cruris 1/3 inferior	None	skin graft	Distal tibia and fibula	follow with splint
10	43	62	traffic accident	cruris 1/3 inferior	Acinetobacter Baumanni	Rectus abdominus musculocutan free flap	Distal tibia and fibula	K wire
11	41	28	falling from high	cruris 1/3 inferior	Psuedomonas Aerginosa	Rectus abdominus musculocutan free flap	Distal tibia and fibula	Intramedullary screw
12	28	41	traffic accident	cruris 1/3 inferior +anterior part of foot	Enterobacter, Enterecoccus	Sural arter fasciocutaneous flap	Talus	External fixator
13	47	0	Plate exposition	cruris 1/3 inferior	None	Hemisolues muscle flap with inferior pedicle and skin graft (perforatör flap)	Distal tibia and fibula	Plate and screw
14	66	15	traffic accident	cruris 1/3 superior	none	gastrocnemius muscle flap and skin graft	Proksimal tibia	Intramedullary screw
15	54	48	work accident	dorsal side of foot	Corynebacterium Striatum, Achromo-bacter Xylosoxidans	skin graft	Metatarsal bone	K wire
16	70	26	traffic accident	cruris 1/3 inferior	Psuedomonas Aerginosa, Corynebacte-rium Striatum	skin graft	Distal fibula	K wire
17	20	16	Traffic Acci-dent	Dorsal Side of foot	Corynebacterium Striatum	Skin graft	Talar and Metatarsal bones	follow with splint
18	18	26	firearm injury	anterior part of foot	Stafilococus Aureus, Brevundimonas Diminuta	VY fasciocutaneous flap and skin graft	Middle phalanx	K wire

Table 2: Distribution of descriptive features

		n	%
Age (year)	Min-Max(Median)	18-86 (50,5)	
	Mean±Sd	49,94±22,51	
	< 50 years	9	50,0
	≥ 50 years	9	50,0
	< 60 years	12	0,67
	≥ 60 years	6	0,33
Etiology	Firearm injury	6	33,3
	Others	12	66,7
Location	Proksimal	5	27,8
	Distal	13	72,2
Stabilization	External fixation	8	44,4
	İnternal fixation	10	55,6
Tissue biopsy cultures	Reproduction (-) Reproduction (+)	6 12	33 67
Time from initial injury to surgical reconstructions (day)	Min-Max (Median)	0-75 (21,5)	
	Med±Sd	25,50±19,75	
Morbidity	Have at least one	7 (38,9)	
	None	11 (61,1)	

Table 3: Evaluation of time from ınitial ınjury to surgical reconstructions according to descriptive features

		Time from initial injury to surgical reconstructions (day)			
		n	Median (Min-Max)	Mean±Sd	p
Age (year)	< 50 years	9	16 (0-62)	22.4±19.4	0.452
	≥ 50 years	9	22 (10-75)	28.5±20.7	
	< 60 years	12	21 (0-75)	27,9±23,8	0.925
	≥ 60 years	6	21,5 (12-28)	20,6±6,1	
Tissue biopsy cultures	Reproduction (-) Reproduction (+)	6 12	12 (0-28) 26 (6-75)	12.6±3.7 31.9±5.9	0.032*
Etiology	Firearm injury	6	18 (6-75)	25.5±25.3	0.606
	Others	12	23.5 (0-62)	25.5±17.6	
Location	Proksimal	5	10 (6-15)	10.8±3.7	0.012*
	Distal	13	26 (0-75)	31.1±20.5	
Stabilization	External fixation	8	18.5 (6-75)	25.3±22.7	0.567
	İnternal fixation	10	26 (0-62)	26.6±18.3	
Additional morbidity	Have at least one	7	22(12-75)	33.5±24.6	0,239
	None	11	16 (0-48)	20.3±14.9	

Mann Whitney U Test *$p<0.05$

In such cases, the cross-leg flap method can be attempted as an alternative to amputation, although it is generally no longer preferred. Using this method, we were able to spare 2 patients' extremities despite the development of ankylosis due to the injuries being at ankle level. This preserved the patients' ability to walk without prosthetics.

Local muscle flap options can also be used successfully in selected cases. The ankle area has limited soft tissue and plate exposure is often observed if plate and screw fixation is used, especially in elderly patients. Applying a distally pedicled hemisoleus flap can be effective in elderly patients with multiple comorbidities due to advantages such as shorter surgery time and the use of spinal or epidural anesthesia. However It was reported, when the entire muscle is mobilized based on the distal pedicle the flap a high failure rate[18]. Distally pedicled hemisoleus is a reliable flap, although it has a weaker blood supply than the superiorly pedicled model. Although graft loss over the flap is common, we did not encounter any muscle necrosis. However, a patient in our series who underwent plate and screw fixation due to distal fibula fracture developed a small area of exposure distal to the defect 1 month later, which was repaired using a perforator flap. This may be because the relatively lower muscle volume resulting from the use of a distally pedicled flap did not provide thick enough coverage of the plate. However, we did not encounter any problems regarding the muscle thickness in patients whose plate and screw fixation were removed.

Conclusion

Complicated lower extremity injuries are difficult to manage and reconstruct due to the anatomical structures as well as the mechanism of injury and high probability of complication. Not only the factors like the bacterial growth but also the level of the injury is also affected the time from initial injury to late surgical reconstruction. With the recent widespread use of vacuum-assisted closure systems, appropriate granulation can be achieved for the graft. In large defects and injuries with high potential for dead space, free muscle and fasciocutaneous flaps are used as the gold standard. However, cross-leg flaps can be used in selected patients to spare the extremity in patients with severe soft tissue and bone damage due to firearm injury, especially buckshot, when the recipient vessels are problematic. Local muscle flaps can be safely used with different pedicle options. When one head of the triceps surae muscles is used as a flap, functional donor-site morbidity is less severe in patients with complete healing of the initial injury. It is emphasized that normal walking can be achieved, although a deficit may be observed when walking fast and climbing[19]. The patients who early soft tissue reconstruction could not be performed, the time from initial injury to surgical reconstructions were depended on bacterial growth an localization of injury in the complicated lower extremity injuries.

Conflict of interest

The authors declare that they have no conflict of interest.

Ethical approval:

The approval of Cumhuriyet University Ethical Comittee was satisfied. Decision No :2020-03/21

Financial disclosure:

No financial assistancent were received.

Informed consent:

Our study is a case series

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