JOURNAL OF PLASTIC SURGERY AND HAND SURGERY
2023, VOL. 57, NOS. 1–6, 388–392
https://doi.org/10.1080/2000656X.2022.2142599

ARTICLE

10-Year single center experience in lower limb reconstruction with free muscle flaps – factors influencing complications in 266 consecutive cases

Inga S. Besmens[a], Florian S. Frueh[a], Christina Gehrke[a], Sophie Knipper[b], Pietro Giovanoli[a] and Maurizio Calcagni[a]

[a]Department of Plastic Surgery and Hand Surgery, University Hospital Zurich, Zurich, Switzerland; [b]Martini-Klinik Prostate Cancer Center, University Hospital Hamburg-Eppendorf, Hamburg, Germany

ABSTRACT

The anatomy and technique of free muscle flaps – in particular gracilis flap and latissimus dorsi flap – in lower extremity reconstruction have been well described. There is a paucity of data on potential risk factors in larger patient series that affect the outcome. The objective of this study was to address this lack of knowledge by reporting outcomes and complications of free muscle flaps as a primary option in lower extremity reconstruction. From 2009 to 2020, a total of 253 consecutive patients with soft tissue defects of the lower limb from trauma, infection or malignancies underwent lower extremity reconstructive surgery with 266 free muscle flaps. Complications requiring revision surgery were noted in 36.1% of cases. Total flap loss occurred in 10.5% of cases. Patients requiring revision surgery were older, more likely to be female, more likely to be active smokers, and more likely to have a higher ASA score. Lower extremity reconstruction with free muscle flaps has a relevant complication rate that both patient and reconstructive surgeon need to be aware of. Prospective studies should try to further assess the factors affecting the outcome.

ARTICLE HISTORY
Received 31 March 2022
Revised 22 September 2022
Accepted 28 October 2022

KEYWORDS
Lower extremity reconstruction; free muscle flaps; outcomes; complications

Introduction

Lower limb reconstruction using free flaps is one of the cornerstones of plastic surgery [1]. In patients with complex substance loss, free tissue transfer is the preferred option for limb salvage [2]. Microsurgical techniques afford the opportunity to tailor flaps to defects providing optimal functional and aesthetic outcomes [3].

The discussion which type of flap is superior in lower limb reconstruction is ongoing. However, recent evidence indicates that both fasciocutaneous and muscle flaps are characterized by comparable rates of limb salvage and functional recovery [4]. In our department, we commonly use free muscle flaps for reconstruction of complex lower limb injuries. Muscle flaps provide a strong local blood supply, which is considered advantageous, particularly for the treatment of contaminated wounds [5]. Moreover, denervated muscle flaps shrink over time, ultimately providing a better contour [6]. This is of high functional relevance, especially in the foot and ankle region. While the anatomy and technique of free muscle flaps, such as the gracilis and latissimus dorsi flap are well described, there is a paucity of data on outcomes and potential risk factors in larger patient series. The objective of this study was an outcome and complication analysis of free muscle flaps in lower limb reconstruction.

Materials and methods

From 2009 to 2020, a total of 253 consecutive patients with soft tissue defects of the lower limb following trauma, infection or malignancies underwent lower limb reconstruction with 266 free muscle flaps, specifically free gracilis and latissimus dorsi flaps. These patients were identified through an IT-based search of all patients' records. After approval from the Local Ethics Committee had been obtained, data from all above-mentioned patients were included in this study. Medical files of the patients were reviewed retrospectively in the time from December 2020 to March 2021 and analyzed for patient demographics, comorbidities including nicotine abuse, peri- and postoperative details, flap survival, and complications. Smoking and diabetes are two common factors contributing to the development of arteriosclerosis and the resulting ischemia and microangiopathies contribute in varying degrees to the adverse healing [7]. Additionally, microvascular anastomosis in atherosclerotic vessels presents a challenge in itself [8], which is why these factors were deemed of interest. The preoperative American Society of Anesthesiologists (ASA) score was documented for each patient. This score as well as patient age has been related to worse outcomes in reconstructive microsurgery [9] and was therefore considered relevant. Gracilis and latissimus dorsi are the two workhorse muscle flaps, both have advantages and disadvantages leading to the question of whether one would generally be related to more complications than the other. Additionally, the cause of the soft tissue defect needing free flap cover was assessed and analyzed whether compound defects including an underlying fracture (and could therefore be considered more complex) or delayed defects on the basis of infection would relate to worth outcomes as might be expected due to their complicated nature compared to acute traumatic soft tissue defects.

CONTACT Inga S. Besmens inga.besmens@usz.ch Department of Plastic Surgery and Hand Surgery, University Hospital Zurich, Rämistrasse, 100 8091 Zurich, Switzerland

Outcomes of interest

The rate of revision surgery was determined. Surgical outcomes were registered as total or partial flap loss, arterial or venous thrombosis, hematoma or seroma requiring revision surgery. Additionally, outcomes concerning absolute flap survival were analyzed. All data were obtained from the written reports in the digital patient files.

Surgical methods and follow-up regimes

Patients were admitted directly to the department of plastic surgery in case of (semi-) elective free flap surgery or were transferred from other departments once the need for a free flap had been determined. Preoperatively, an angiography of the recipient leg was acquired to identify appropriate recipient arteries. Patients received either a free gracilis or a free latissimus dorsi flap. The donor site was chosen according to defect size and configuration, concomitant injuries, patient wishes and/or convenience of intraoperative patient positioning. The flaps were harvested in the standard technique described in the available literature [10,11]. All flaps were harvested without a skin island but instead were covered with a split-thickness skin graft from the upper thigh after revascularization of the flaps. If both anterior and posterior tibial artery provided a potent vascularization of the foot, anastomoses would be performed end-to-end to the vessel that had been decided on. If vascularization of the foot was deemed questionable arterial anastomoses would be performed in an end-to-side fashion.

A minimum of one venous anastomosis was performed with a coupler device. Postoperatively flap viability was checked clinically, via ICG, or via Doppler regularly. Patients were restricted to bed rest for five days. The first dressing change was performed on the 5th day post-surgery and patients would then start a dangling regime that increased dangling time over three consecutive days. A light compression was applied during those three days and customized compression stockings were applied thereafter.

Depending on concomitant injuries, patients would be released around 10 days post-surgery. Regular dressing changes will be performed by the patient, home nursing services or the family healthcare providers. Patients would be followed up in our outpatient clinic at 2 weeks, 6 weeks, 12 weeks, and as deemed necessary (in accordance with concomitant injuries) after release from the hospital.

Statistical analysis

Descriptive statistics included frequencies and proportions for categorical variables. Means, medians and ranges were reported for continuously coded variables. The Chi-square was used to assess the statistical significance in proportions differences. The *t*-test and Kruskal–Wallis test were used to evaluate the statistical significance of means and median differences. Univariable and multivariable logistic regression models were used to test the relationship between revision and several variables, namely age, sex, smoking status, diabetes mellitus history, ASA score, reason for the soft tissue defect, flap location and flap type.

The discrimination of the model was tested using the area under the receiver operating characteristics curve (AUROC). R software environment for statistical computing and graphics (version 3.4.3) (Vienna, Austria) was used for all statistical analyses. All tests were two-sided with a level of significance set at $p < 0.05$.

Results

Between 2009 and 2020, 266 consecutive reconstructive surgeries with free muscle flaps on the lower limb were performed in 189 male and 77 female patients (Table 1). The gracilis flap was used in 138 and the latissimus dorsi flap in 128 cases. Median patient age was 47 years (interquartile range (IQR): 34–57 years). Overall, 13 (4.9%) patients had diabetes mellitus and 97 (36.5%) patients were active smokers. The majority of patients (208 patients, 78.2%) was categorized as either ASA I (65 patients, 24.4%) or ASA II (143 patients, 53.8%).

The defects were located on the foot in 81 (30.5%) patients, on the ankle in 53 (19.9%) patients, on the knee in 14 (5.3%) patients, on the upper thigh in nine (3.4%) patients and on the lower thigh in 109 (41.0%) patients. In 69 (25.9%) patients, an infection was the underlying cause that led to the need for flap coverage whereas 149 (56.0%) patients sustained traumatic soft tissue loss in combination with an underlying fracture and 29 (10.9%) with no underlying fracture. In 19 (7.1%) cases, the soft tissue loss was due to the need of tumor resection. Before definite flap coverage of the defects, a median of three prior surgeries (range 0–10) was performed to achieve a stable wound bed.

Complications requiring revision surgery were noted in 96 (36.1%) cases. These complications ranged from seromas to complete flap loss (see Table 1). Total flap loss occurred in 28 (10.5%) cases. Donor site complications were noted in 12 cases (4.5%). Patients requiring revision surgery were older (50 vs. 46 years in non-revised group, $p = 0.03$), more likely to be active smokers (45.8 vs. 31.2% in non-revised group, $p = 0.02$) and more likely to have a higher ASA score (ASA III–IV: 30.2 vs. 17.1% in non-revised group, $p = 0.02$).

Subgroup analyses of patients with complete flap loss revealed that they were more likely to be active smokers (57.1 vs. 34.0% in the flap survival group, $p = 0.03$).

In multivariable logistic regression models evaluating the risk of revision surgery (see Table 2), higher age represented an independent predictor of higher risk for revision surgery (odds ratio (OR): 1.02, $p = 0.04$). Moreover, female sex (OR: 1.94, $p = 0.03$), ASA III–IV (OR: 2.58, $p = 0.03$), active smoking status (OR 2.01, $p = 0.01$) and latissimus dorsi-flap (OR: 1.88, $p = 0.02$) also represented independent predictors of higher risk for revision surgery.

Discussion

Free flap surgery has become a routine procedure for the reconstruction of complex soft-tissue defects of the lower limb [12]. Fasciocutaneous flaps such as the anterolateral thigh (ALT) flap as well as muscle flaps such as the gracilis flap are routinely used. The discussion about relative advantages and disadvantages of each flap type is still open [13] but outcomes generally seem to be comparable. In our department, free muscle flaps are the first choice for reconstruction of complex lower limb injuries.

In our study, we describe the outcome of free muscle flaps for lower limb reconstruction in a large male and female cohort with several interesting findings. A rather high complication rate of 35% was observed. In 12 cases (12.5%), donor site hematomas, infection or seromas requiring operative revision were noted. There were 26 (27%) partial flap losses and 15 emergency pedicle revision surgeries by which flap salvage was achieved in cases of postoperative vascular occlusion.

Major complications requiring operative intervention of free flaps to the lower limb are reported to be ~16% [3]. The same study found additional minor complications in 21.1%, resulting in a similar total complication rate. Wettstein et al. reviewed 197

Table 1. Patient variables and their effect on revision surgery rate.

Variables		Overall	No revision	Revision surgery	*p* Value
Age	Median	47	46	50	0.03
	IQR	34–57	34–55	37.8–59	
Gender (male/female)	Male patients	189 (71.1)	128 (75.3)	61 (63.5)	0.05
	Female patients	77 (28.9)	42 (24.7)	35 (36.5)	
Diabetes	No	253 (95.1)	165 (97.1)	88 (91.7)	0.10
	Yes	13 (4.9)	5 (2.9)	8 (8.3)	
smoking	No	169 (63.5)	117 (68.8)	52 (54.2)	0.02
	Yes	97 (36.5)	53 (31.2)	44 (45.8)	
ASA	1	65 (24.4)	51 (30)	14 (14.6)	0.02
	2	143 (53.8)	90 (52.9)	53 (55.2)	
	3	54 (20.3)	27 (15.9)	27 (28.1)	
	4	4 (1.5)	2 (1.2)	2 (2.1)	
Flap type	Gracilis	138 (51.9)	97 (57.1)	41 (42.7)	0.03
	Latissimus dorsi	128 (48.1)	73 (42.9)	55 (57.3)	
Cause of soft tissue defect	Infection	69 (25.9)	40 (23.5)	29 (30.2)	0.66
	Trauma with underlying fracture	149 (56)	98 (57.6)	51 (53.1)	
	Trauma without concomitant fracture	29 (10.9)	20 (11.8)	9 (9.4)	
	Tumor	19 (7.1)	12 (7.1)	7 (7.3)	
Defect localization	Ankle/foot	134 (50.4)	84 (49.4)	50 (52.1)	0.28
	Knee/lower thigh	123 (46.2)	78 (45.9)	45 (46.9)	
	Upper thigh	9 (3.4)	8 (4.7)	1 (1)	
Complications leading to revision surgery		170 (63.9)	170 (100)	0 (0)	1.39
	Donor site: hematoma	6 (2.3)	0 (0)	6 (6.2)	
	Donor site: infection	1 (0.4)	0 (0)	1 (1)	
	Donor site: seroma	5 (1.9)	0 (0)	5 (5.2)	
	Recipient site: infection	2 (0.8)	0 (0)	2 (2)	
	Recipient site: hematoma	12 (4.5)	0 (0)	12 (12.5)	
	Partial flap loss	26 (9.8)	0 (0)	26 (27.1)	
	Total flap loss	28 (10.5)	0 (0)	28	
	Venous revision	12 (4.5)	0 (0)	12 (12.5)	
	Arterial revision	3 (1.1)	0 (0)	3 (3.1)	
	Wound healing disturbance	1 (0.4)	0 (0)	1 (1)	
Total flap loss	No	238 (89.5)	170 (100)	68 (70.8)	4.61
	Yes	28 (10.5)	0 (0)	28 (29.2)	

Table 2. Multivariable logistic regression model for prediction of revision.

		Confidence interval		*p* Value
Variables	Odds ratio	2.5%	97.5%	
Age (continuously coded)	1.02	1.00	1.04	0.04
Sex				
Male	Ref.			
Female	1.94	1.09	3.46	0.03
ASA status				
ASA 1	Ref.			
ASA 2	1.75	0.86	3.73	0.13
ASA 3–4	2.58	1.11	6.15	0.03
Smoking status				
No	Ref.			
Yes	2.01	1.17	3.49	0.01
Flap type				
Gracilis flap	Ref.			
Latissimus dorsi flap	1.88	1.10	3.25	0.02

consecutive free flap reconstructions in the lower limb. They also found an overall complication rate of 40%, ranging from minor wound dehiscence to total flap loss [14].

In our analysis, we found several predictors for higher complication rates. First, older patients were more likely to suffer complications leading to the need for revision surgery. Tholen et al. reported on their experience with free flap reconstruction of the lower limb in the elderly (>60 years) [9,15]. Even though a higher risk was noted in their study, free flap reconstruction of lower limb defects in the elderly patient was deemed a reasonable alternative to amputation when other options are limited. Patient and surgeon, however, need to be aware of patients' age as an additional risk factor for this type of surgery.

Second, the need for revision surgery was also higher in female patients. 45.5% of the free flaps performed in women required some sort of revision surgery while in comparison only 31.6% of flaps performed in men required additional surgery. To the best of our knowledge, female gender as a risk factor for complications after free flap coverage of the lower extremity has not yet been described in the literature. Since the prevalence of vascular disease increases for women after menopause [16], a previously non-diagnosed peripheral vascular disease may have been considered a factor influencing the postoperative outcome. However, this was ruled out as the median female age overall was 29 years and 33 years in women suffering from complications. Thirty-five percent of the women included in this study were active smokers which is comparable to the 37% of males. We did not find any confounding factors making women more susceptible to complications. For further clarification of this finding, prospective studies should evaluate the influence of gender on lower limb reconstruction surgeries.

Third, the revision rate was higher in active smokers (54.2% vs. 45.8%). Smoking is known as an independent predictor for future amputations in patients undergoing free flap reconstruction in the lower limb [17]. In breast reconstruction with free flaps, smoking is contraindicated with prohibitively high complication rates. At least four weeks of abstinence are recommended [18]. In contrast, this approach is not practical in an emergency setting, but we strongly recommend adhering to a similar principal in electively scheduled free flaps to the lower limb.

Fourth, an elevated risk for overall complications in high risk patients (ASA III and IV) was observed. The ASA classification is accepted as a significant predictor of overall complications in microsurgical free flap reconstruction of the breast [19]. The purpose of the ASA system is to assess and communicate a patient's pre-anesthesia medical co-morbidities. A higher ASA score will thus relate to a more complex patient. Interestingly, other studies

have indicated that free flap reconstruction for lower limb defects in high-risk patients can be a safe and reliable procedure for selected patients when an experienced multidisciplinary team is involved [20]. We did not find higher total flap loss rates in patients with an ASA score of III and IV and therefore agree that lower limb reconstruction is possible in these patients when comorbidities are appropriately addressed in the pre-, intra- and postoperative treatment regime.

Fifth, the use of LD flaps presented a statistically significant predictor for the need for revision surgery. The LD flap has a very constant anatomy [21] and we do not presume that raising of the flap can be considered a reason for a higher complication rate in these patients. The risk of total flap loss is usually quoted between 5.3% [22] and 13% [4]. Since generally larger defects with more extensive underlying trauma or infection need to be covered by a larger muscle flap, this may be the explanation for the increased risk for revision surgery. In a large flap, we sometimes experience partial flap loss distal to a watershed line. This phenomena is specifically true for the latissimus dorsi free flap, a type 5 flap according to Mathes and Nahai with multiple minor segmental pedicles. Moreover, one could assume that the majority of donor site complications would be found in the larger latissimus dorsi donor site. Indeed, in our study, 10 of the 17 donor site complications registered were found in latissimus cases. The absolute survival rate of gracilis and latissimus dorsi flap however are similar Franco et al. report a single surgeon experience with gracilis flaps to the leg with a success rate of 92% [23] while Knobloch et al. report on overall free latissimus dorsi flap survival of 95% [24]. Having the data from our study in mind, we recommend using a gracilis muscle flap instead of a latissimus dorsi flap whenever possible. When used correctly, the gracilis flap can be easily used to cover large defects ($<100\,cm^2$) [25].

Several other factors were evaluated. Specifically, no significant difference concerning the risk for complications for specific defect locations or cause of the defect was found. A clean wound bed is the starting point of any soft tissue reconstruction [26]. We perform serial debridements before definite free flap surgery as often as necessary. Once proper debridement has been achieved, the prior presence of an infection should not play a role toward the reconstruction. The principles of microsurgery are the same throughout the entire leg, which is why the defect location may not have an effect on complications. Moreover, diabetes as a comorbidity did not have an influence on the development of complications in our cohort. This may be due to the fact that only comparably few of our patients were diagnosed with diabetes [13].

There is an ongoing discussion in reconstructive plastic surgery about which type of flap is superior, fasciocutaneous flaps or muscle flaps. Cho et al. achieved comparable rates of limb salvage and functional recovery for both flap types [4]. In our patients, we regularly see that muscle flaps adapt nicely to any defect form and depth providing a strong local blood supply to often irregular and contaminated wounds [5]. Moreover, we know that the denervated muscle shrinks significantly over time ultimately providing a good contour [6] which is of course of significant functional relevance especially in the foot and ankle region. The fact that muscle shrinks and fibrosis however makes it difficult to re-elevate after time for potential orthopedic follow-up procedures. We did not evaluate flap complications related to re-elevation but depending on patient characteristics like number of competent vessels in the leg or comorbidities we feel it can be more advisable to perform follow-up incisions through the then randomized muscle flap instead of re-elevating the entire flap as this might lead to a necrosis of the most distal part of the flap. Identifying the timeline for flap randomization is typically done from experience taking many patient related factors into account. In fasciocutaneous flaps, re-elevation of the flap is usually less complicated making this a straight forward approach in orthopedic follow-up surgery. But Paro et al. found that fasciocutaneous flaps are more likely to require elective flap revision surgery [27]. We have a similar experience but are aware that even muscle flaps will sometimes need secondary revisions to reach the best shape possible. It is therefore of paramount importance in our opinion to stretch out the muscle flaps, ideally in combination with epimysiotomies to avoid bulkiness [25].

There are several limitations to this study. It is a retrospective study and thus may be prone to observer bias. The conclusions will need to be supported by prospective data for greater impact. Additionally, as we are presenting consecutive cases, patients were operated on by different surgeons. These adhere to a department standard concerning the postoperative regime, but minor deviations based on personal preference might have been made. Lastly, we did not specifically assess and describe functional outcomes or document the return to work, which are key factors when evaluating the reconstructive outcome.

Conclusions

Lower limb reconstruction with free muscle flaps is characterized by a relevant complication rate that both patient and reconstructive surgeon need to be aware of. Whenever possible, patients should quit smoking prior to reconstructive surgery as this represents a major risk for complications. Moreover, female gender seems to have an effect on the overall complication rate. Additionally, using a gracilis muscle flap instead of a latissimus dorsi flap may be beneficial whenever possible. Prospective studies are required to support the findings of this investigation.

Ethics statement

Approval from the Local Ethics Committee was obtained.

Disclosure statement

All authors declare that there is no conflict of interest.

ORCID

Inga S. Besmens http://orcid.org/0000-0002-3821-7163

References

[1] Shokrollah K, Whitaker I, Nahai F. Flaps: practical reconstructive surgery. New York (NY): Thieme Publishers; 2017.
[2] Pu LLQ, Medalie DA, Rosenblum WJ, et al. Free tissue transfer to a difficult wound of the lower extremity. Ann Plast Surg. 2004;53(3):222–228.
[3] Fischer JP, Wink JD, Nelson JA, et al. A retrospective review of outcomes and flap selection in free tissue transfers for complex lower extremity reconstruction. J Reconstr Microsurg. 2013;29(6):407–416.
[4] Cho EH, Shammas RL, Carney MJ, et al. Muscle versus fasciocutaneous free flaps in lower extremity traumatic reconstruction: a multicenter outcomes analysis. Plast Reconstr Surg. 2018;141(1):191–199.

[5] Calderon W, Chang N, Mathes SJ. Comparison of the effect of bacterial inoculation in musculocutaneous and fasciocutaneous flaps. Plast Reconstr Surg. 1986;77(5):785–794.
[6] May JW, Rohrich RJ. Foot reconstruction using free microvascular muscle flaps with skin grafts. Clin Plast Surg. 1986;13(4):681–689.
[7] Drazan L, Veselý J, Leypold J, et al. Microsurgery in the diabetic foot. Acta Chir Plast. 2001;43(1):11–15.
[8] Pafitanis G, Kyprianou K, Chen H-C. Microvascular anastomosis in atherosclerotic vessels: technical challenges and recommendations. J Plast Reconstr Aesthet Surg. 2021;74(7):1633–1701.
[9] Klein HJ, Fuchs N, Mehra T, et al. Extending the limits of reconstructive microsurgery in elderly patients. J Plast Reconstr Aesthet Surg. 2016;69(8):1017–1023.
[10] Lyons ME, Goldman JJ. Gracilis tissue transfer. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 [cited 2022 Jul 3]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK559046/
[11] Vincent A, Hohman MH. Latissimus dorsi myocutaneous flap. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2022 [cited 2022 Jul 3]. Available from: http://www.ncbi.nlm.nih.gov/books/NBK564377/
[12] Bigdeli AK, Thomas B, Falkner F, et al. Microsurgical reconstruction of extensive lower extremity defects with the conjoined parascapular and latissimus dorsi free flap. Microsurgery. 2020;40(6):639–648.
[13] Paro J, Chiou G, Sen SK. Comparing muscle and fasciocutaneous free flaps in lower extremity reconstruction – does it matter? Ann Plast Surg. 2016;76(Suppl. 3):S213–S215.
[14] Wettstein R, Schürch R, Banic A, et al. Review of 197 consecutive free flap reconstructions in the lower extremity. J Plast Reconstr Aesthet Surg. 2008;61(7):772–776.
[15] Tholen RH, Hammond DC, Cooney WP, et al. Free flap reconstruction of the lower extremity in the elderly. Eur J Plast Surg. 1992;15(2):15.
[16] Kuller LH, Matthews KA, Edmundowicz D, et al. Incident coronary artery calcium among postmenopausal women. Atherosclerosis. 2008;200(2):278–285.
[17] Karamanos E, Ahmad H, Makhani AA, et al. Development and validation of scoring system to predict secondary amputations in free flap reconstruction. Plast Reconstr Surg Glob Open. 2020;8(11):e3211.
[18] Chang DW, Reece GP, Wang B, et al. Effect of smoking on complications in patients undergoing free TRAM flap breast reconstruction. Plast Reconstr Surg. 2000;105(7):2374–2380.
[19] Chang EI, Vaca L, DaLio AL, et al. Assessment of advanced age as a risk factor in microvascular breast reconstruction. Ann Plast Surg. 2011;67(3):255–259.
[20] Maldonado AA, Steinebach R, Morillo MC, et al. Evaluation of the American Society of Anesthesiologists Physical Status classification system in risk assessment for lower extremity reconstruction with free tissue transfer. J Reconstr Microsurg. 2021;37(7):622–630.
[21] Wolff K-D, Hölzle F. Latissimus dorsi flap. Raising of microvascular flaps [Internet]. Berlin/Heidelberg: Springer-Verlag; 2005 [cited 2021 Mar 13]. p. 65–81. Available from: http://link.springer.com/10.1007/3-540-27005-1_4
[22] Li X, Cui J, Maharjan S, et al. Reconstruction of the foot and ankle using pedicled or free flaps: perioperative flap survival analysis. PLOS One. 2016;11(12):e0167827.
[23] Franco MJ, Nicoson MC, Parikh RP, et al. Lower extremity reconstruction with free gracilis flaps. J Reconstr Microsurg. 2017;33(3):218–224.
[24] Knobloch K, Herold C, Vogt PM. Freier Latissimus-dorsi-Transfer zur Rekonstruktion von Weichteildefekten der unteren Extremität. Oper Orthop Traumatol. 2012;24(2):122–130.
[25] Calotta NA, Pedreira R, Deune EG. The gracilis free flap is a viable option for large extremity wounds. Ann Plast Surg. 2018;81(3):322–326.
[26] Ger R. The management of open fracture of the tibia with skin loss. J Trauma. 1970;10(2):112–121.
[27] Paro J, Chiou G, Sen SK. Comparing muscle and fasciocutaneous free flaps in lower extremity reconstruction—does it matter? Ann Plast Surg. 2016;76(Suppl. 3):S213–S215.