Injury 52 (2021) 3489–3497

Contents lists available at ScienceDirect

Injury

journal homepage: www.elsevier.com/locate/injury

Soft-tissue reconstruction in lower-leg fracture-related infections: An orthoplastic outcome and risk factor analysis

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ARTICLE INFO

Article history:
Accepted 13 July 2021

Keywords:
Fracture-related infection
Soft-tissue reconstruction
Flap
Fracture
Nonunion
Infection
Orthoplastic
Lower leg

ABSTRACT

Introduction Fracture-related infection (FRI) is a severe post-traumatic complication which is occasionally accompanied by a deficient or even avital soft-tissue envelope. In these cases, a thoroughly planned orthoplastic approach is imperative as a vital and intact soft-tissue envelope is mandatory to achieve fracture union and infection eradication. The aim of this study was, to analyse if soft-tissue reconstruction (STR) without complications is associated with a better long-term outcome compared to FRI patients with STR complications. In particular, it was investigated if primary flap failure represented a risk factor for compromised fracture union and recurrence of infection.

Patients and Methods Patients with a lower leg FRI requiring STR (local, pedicled and free flaps) who were treated from 2010–18 at the University Hospital Basel were included in this retrospective analysis. The main outcome measure was the success rate of STR, further outcome measures were fracture nonunion and recurrence of infection.

Results Overall, 145 patients with lower leg FRI were identified, of whom 58 (40%) received STR (muscle flaps: $n = 38$, fascio-cutaneous flaps: n=19; composite osteo-cutaneous flap: $n = 1$). In total seven patients required secondary STR due to primary flap failure. All failures and flap-related complications occurred within the first three weeks after surgery. Secondary STR was successful in all cases. A high Charlson Comorbidity Index Score was a significant risk factor for flap failure ($p = 0.011$). Out of the 43 patients who completed the 9-month follow-up, 11 patients presented with fracture nonunion and 12 patients with a recurrent infection. Polymicrobial infection was a significant risk factor for fracture nonunion ($p = 0.002$). Primary flap failure was neither a risk factor for compromised fracture consolidation ($p = 0.590$) nor for recurrence of infection ($p = 0.508$).

Conclusion: A considerable number of patients with lower-leg FRI required STR. This patient subgroup is complex and rich in complications and the long-term composite outcome demonstrated a high rate of compromised fracture consolidation and recurrent infections. It appears that secondary STR should be performed, as primary flap failure was neither a risk factor for compromised fracture consolidation nor for recurrence of infection. We propose to monitor these patients closely for three weeks after STR.

Introduction

Fracture-related infection (FRI) is a severe post-traumatic complication that develops in 1% after closed low energy fractures and in up to 30% after complex open lower leg fractures [1,2]. In addition to the location and severity of the initial injury, the

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https://doi.org/10.1016/j.injury.2021.07.022

risk of developing a FRI depends on concomitant injuries and on pre-existing local and systemic comorbidities. These factors do not only influence the risk of establishing an infection but also FRI treatment and overall outcome. Beside the anatomical location and impairments of the host's physiology the following factors should considered in FRI treatment: type of implant with accessibility to debridement, disease causing pathogen and susceptibility to biofilm active antibiotics, time interval between initial trauma and FRI treatment, stability of the osteosynthetic construct, and vitality of the soft-tissue envelope. Based on these factors, one of the main surgical concepts (debridement and implant retention (DAIR) vs. implant removal/ exchange) and one of the main antimicrobial concepts (infection eradication or suppression) are chosen to achieve the aims of FRI treatment. The central goals are: [1] Fracture consolidation; [2] Eradication of infection or in certain cases suppression of infection until fracture consolidation is achieved; [3] Healing of a competent soft-tissue envelope; [4] Prevention of chronic osteomyelitis; [5] Restoration of functionality [3–6]. A vital and well perfused soft-tissue coverage is mandatory to achieve these goals since it significantly contributes to bone healing and infection eradication. Early involvement of the plastic surgeon does not only allow early reconstruction but also permitting the reconstructed well-vascularized soft-tissue to act early as a vehicle for the transportation essential growth factors, nutrients, host immune cells and systemically applied antibiotics to the fracture area. Furthermore, it poses an antimicrobial barrier that prevents further contamination. An incompetent soft-tissue envelope overlying a FRI site that is not capable of sufficiently contributing to fracture healing and infection eradication, may pose an indication for soft-tissue reconstruction (STR) [2,3,7,8]. Despite its importance outcome data on the course of healing after FRI related STR is scares. Therefore, the central question of this study was, if STR without complications is associated with a better long-term outcome compared to FRI patients with STR complications. In particular, it was investigated if primary flap failure represented a risk factor for compromised fracture union and recurrence of infection. In addition, risk factors for flap failure were analysed.

Ethics committee approval

The study was conducted according to the legal regulations of the Swiss Human Research Act and approved by the local ethical committee (EKNZ 2020-00214). General consent was provided.

Patients and methods

An electronic database of patients treated at the University Hospital Basel from 2010 until 2018 was retrospectively searched for adult patients with lower leg FRI and consequent STR. STR included the use of local, pedicled and free flaps, patients with a full or split thickness skin graft only were excluded. The reconstruction method depended upon the preoperative three-dimensional analysis of the size and components of the composite defect, the vascular status and the comorbidities of the patient [9]. In general, the principle to replace tissue 'like with like' was favoured to achieve the best functional and aesthetic outcome [10]. For example, if the damaged structures consisted of cutaneous, subcutaneous and tendineous tissue reconstruction was performed with a free fascio-tendino-cutaneous antero-lateral thigh (ALT) flap (under the precondition that patient's vascular status and comorbidities allow free flap reconstruction) (Fig. 1). Patient's demographic data and comorbidities as defined by the modified Charlson Comorbidity Index [11], as well as initial fracture and infection details were recorded in a database. FRI was diagnosed if one of following confirmatory criteria of the recently published FRI consensus definition was present [12,13]: (i) presence of fistula, sinus or wound breakdown in communication to the bone or implant; (ii) purulent drainage from the wound or presence of pus during surgery; (iii) presence of phenotypically indistinguishable pathogens identified by culture from at least two separate intraoperatively collected deep tissue/implant sites; (iv) presence of microorganisms in deep tissue samples, as confirmed by histopathological examination with specific staining techniques for bacteria or fungi; or (v) presence of more than five polymorph neutrophils per high power field in deep tissue samples. Difficult-to-treat pathogens were defined as rifampicin-resistant staphylococci, chinolone-resistant gram-negative bacteria, enterococci or fungi [14–16]. The date of the first FRI revision surgery with debridement and tissue sampling, leading to the diagnosis of FRI, was taken as the diagnostic date of FRI.

Outcome analysis

Regular follow-up investigations were performed at four and six weeks, three, six and nine months after STR. The main outcome measure was successful STR which was defined by the presence of an intact and dry soft tissue envelope surrounding the FRI site. Associated risk factors for failure of STR were sought. Further outcome measures were absence of fracture consolidation and cure of infection nine months after STR [17]. Fracture consolidation was defined if at least three of four corticalices had healed [18]. Cure of infection was defined by the absence of recurrent infection during the entire follow-up period. A recurrent infection could be caused by any pathogen and was defined as the occurrence of at least one of the confirmatory criteria in the earlier mentioned definition [12]. Complications were identified as flap-related complications (FRCs) and non-FRCs (e.g. in Table 3) and were classified according to the Clavien-Dindo classification [19].

Statistical analysis

Data were collected with Research Electronic Data Capture software (REDCap, Version 9.1.0, Vanderbilt University) and analysed by using the jamovi project (2020, Version 1.2) and *R* software (*R* Core Team, 2019, Version 3.6). All variables were evaluated for normal distribution with a combination of histograms and Shapiro-Wilk tests. Continuous variables are presented as means with standard deviations and minimum and maximum range when following the Gaussian distribution. For skewed data, the median, interquartile range (IQR) and minimum and maximum range was used. A chi-square test was used to test for associations of categorical variables, and binomial logistic regression was performed for continuous and ordinal independent variables with dichotomous outcomes. All tests were double sided and a p-value of < 0.05 was considered significant.

Results

Patient cohort

During the study period, 145 patients were treated at our centre for lower leg FRI. Of these 58 (40%) patients needed STR around the FRI site (Fig. 2). Demographics and comorbidities are outlined in Table 1. The median time interval between fracture and FRI diagnosis was 93 days (IQR 25 to 278, range seven days to 46 years). All 58 patients completed follow-up four weeks after primary STR. At nine months follow-up, the records of 15 (15/58) patients were incomplete and results from 43 (43/58) patients were available for long-term follow-up investigation.

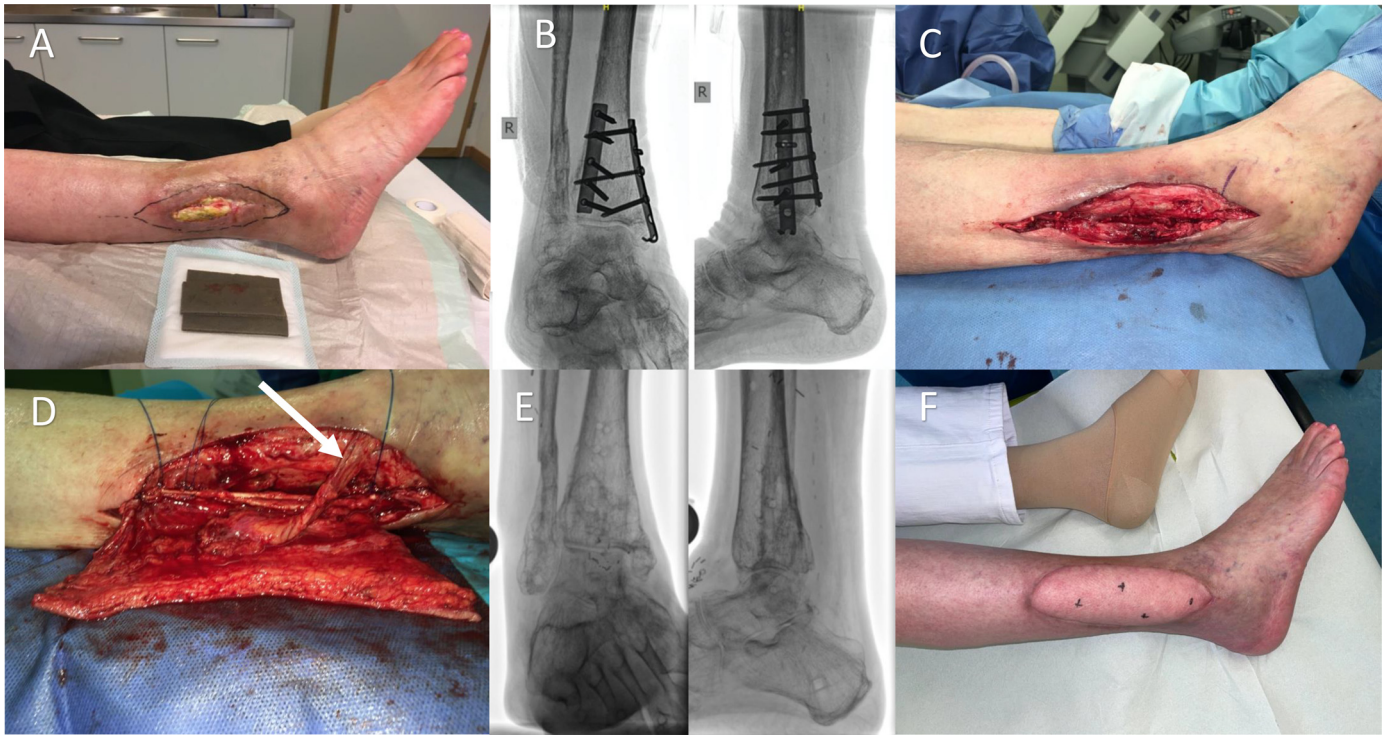

Fig. 1. Clinical presentation of the chronic fistula over the lateral right malleolus with infected and necrotic peroneal tendons and fracture-related infection of the distal fibula six month after ankle fracture (A) corresponding radiograph after removal of the plate osteosynthesis distal fibula hardware (B). The markings demonstrate the planned incision line before (A) and after (C) excision of all chronically infected cutaneous and tendineous tissue. After microvascular anastomosis through a separate medial incision (not on this photograph) and tunneling of the pedicle (arrow), the tendinous tissue (fascia lata) of the free antero-lateral-thigh flap is used to reconstruct the peroneal tendons with the sutures still in place (D). Three months after complete hardware removal and soft-tissue reconstruction complete bony (E) and soft-tissue consolidation is presented (F).

Table 1
Patient characteristics of lower-leg fracture-related infections requiring soft-tissue reconstruction ($n = 58$)

Characteristic	Value
Mean age, years (SD, range)	58.9 (15.5, 23.3–90.2)
Male/female sex	43/15
Median BMI (IQR, range)	25.2 (6.7, 16.6–45.7)
Smoking	28
Arterial hypertension	24
Alcohol abuse	15
Peripheral vascular disease	8
Diabetes	8
Charlson Comorbidity Index score	0: 28 1,2: 21 3,4: 6 ≥ 5: 3

Soft-tissue reconstruction

Patients had undergone a median of three (IQR two to four, range one to eight) debridements before STR. In 15 (15/58) patients, STR was performed during the same operation as the first FRI debridement, whereas in 43 (43/58) patients, it was performed at a later time point.

For primary STR, muscle flaps were used in 38 (38/58) patients, fascio-cutaneous flaps in 19 (19/58) and a composite osteo-cutaneous flap in one (1/58) (Table 2). In total 34 (34/58) local/pedicled and 24 (24/58) free flaps were applied.

In total, 20 (20/58) patients developed 32 complications (Table 3). In total 16 FRCs, requiring surgical revision and 12 FRCs, which were handled without revision surgery were recorded. Four complications were not flap related (Fig. 3). One patient had both an FRC and a non-FRC and five had more than one complication. Seven patients had a partial or total flap failure identified between day 3 and 19 after primary STR. All were successfully reconstructed during secondary STR surgery (Fig. 2). The flap survival rate is illustrated in Fig. 4.

Neither the time span between FRI and STR was a risk factor for STR failure ($p = 0.919$, odds ratio (OR) 1.00, 95% confidence interval (CI) 1.00 to 1.00), nor the number of debridements between FRI and STR ($p = 0.359$, odds ratio (OR) 1.21, 95% confidence interval (CI) 0.81 to 1.82) (Table 4).

The Charlson Comorbidity Index Score was a significant risk factor for flap failure ($p = 0.011$, odds ratio (OR) 1.89, 95% confidence interval (CI) 1.16 to 3.07) (Table 4). However, STR failure rate did not differ between local/pedicled and free flaps ($p = 0.933$, odds ratio (OR) 0.93, 95% confidence interval (CI) 0.19 to 4.61). Patients with free-flap STR developed significantly more severe complications, such as hematoma, flap thrombosis and wound dehiscence, which made surgical intervention necessary (Clavien Dindo ≥ IIIa, $p = 0.001$, OR 7.50, 95% CI 2.01 to 27.9) (Fig. 5).

Fracture *consolidation at long-term follow-up investigation*

At nine months after STR, the fracture was consolidated 32 of 43 patients (Fig. 2). Polymicrobial infection was a significant risk factor for failure of consolidation ($p = 0.002$, OR 0.11, 95% CI 0.02 to 0.50, Table 4). Neither the time span between FRI and STR was a risk factor for fracture non-union ($p = 0.617$, odds ratio (OR) 1.00, 95% confidence interval (CI) 1.01 to 1.22), nor the number of debridements between FRI and STR ($p = 0.125$, odds ratio (OR) 0.76, 95% confidence interval (CI) 0.53 to 1.08) (Table 4).

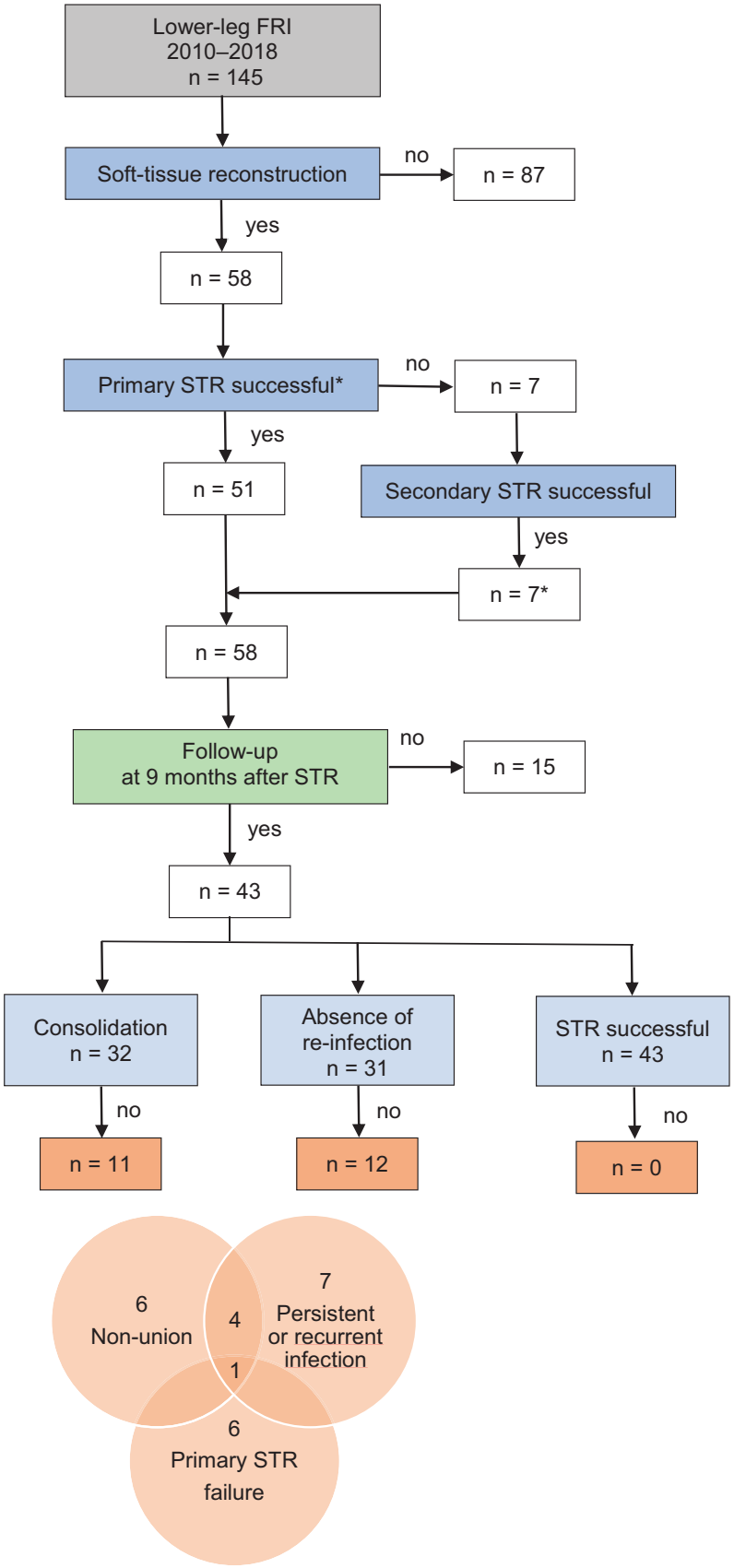

Fig. 2. Patients flow diagram.
FRI, fracture-related infection; STR, soft-tissue reconstruction,*successful STR was documented one and nine months after STR postoperatively (For interpretation of the references to color in this figure, the reader is referred to the web version of this article.).

Table 2
Details of primary soft-tissue reconstruction ($n = 58$)

Muscle flaps	*n*	Fasciocutaneous flaps	*n*	Osteocutaneous flap	*n*
Gracilis (free)	16	Sural	5	Fibula (free)	1
Gastrocnemius	10	Transposition	5		
Peroneus brevis	7	Lateral arm (free)	1		
Latissimus dorsi (free)	3	Anterolateral thigh (free)	4		
Soleus	1	Propeller	2		
Tibialis anterior	1	Rotation	1		
		Groin (free)	1		

Table 3
Complications after soft-tissue reconstruction according to type of flap.

Complication*	Local flaps, *n* (total $n = 10$)	Pedicled flaps, *n* (total $n = 24$)	Free flaps, *n* (total $n = 24$)
FRCs requiring surgical revision	**1**	**4**	**11**
Partial flap loss		2	
Total flap loss	1	1	3
Postoperative flap thrombosis			1
Haematoma		1	5
Wound dehiscence at recipient site			2
FRCs without surgical revision	**2**	**4**	**6**
Fistula formation	1		
Wound healing disorder		3	4
Hematoma without revision		1	
Dehiscence at recipient site	1		1
Dehiscence at donor site			1
Non-FRCs	**1**	**2**	**1**
Cardiac decompensation			1
Pneumonia		1	
Delirium		1	
Depression	1		

FRCs: fracture-related complications.
* Some patients had more than one complication.

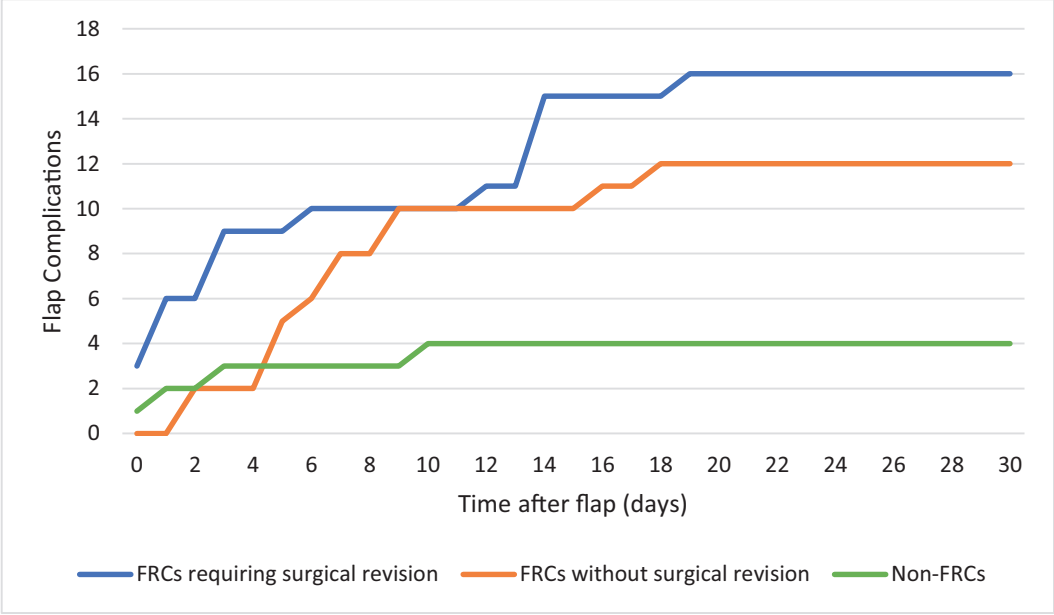

Fig. 3. Flap complications according to time of occurrence and type of complication.
FRC: flap-related complication.

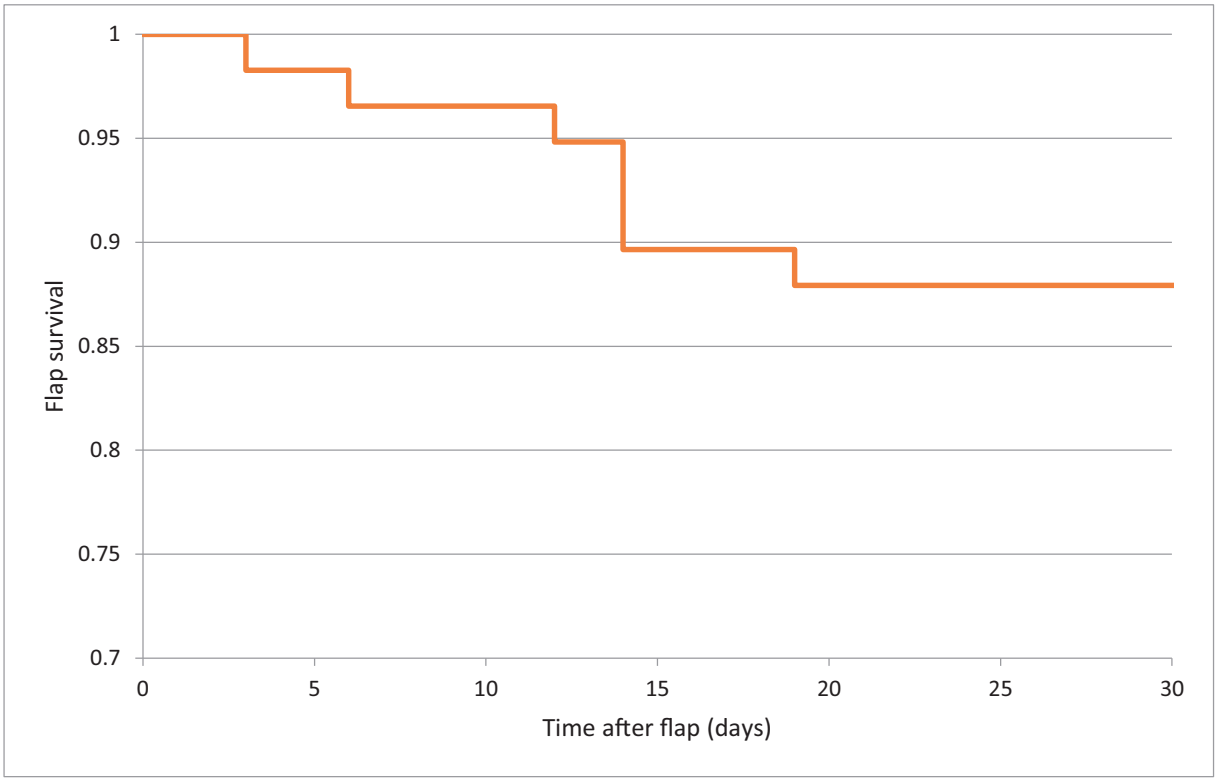

Fig. 4. Flap survival calculated according to Kaplan-Meier method.

Table 4
Comparison of risk factors predicting failure of soft-tissue reconstruction (STR), fracture non-union and persistent or recurrent infection.

Risk factor	STR failure			Fracture non-union			Persistent or recurrent infection		
	OR	95% CI	*p*	OR	95% CI	*p*	OR	95% CI	*p*
Gender	0.16	0.01 to 2.92	0.096	3.33	0.37 to 30.3	0.281	1.46	0.26 to 82.8	0.669
Age	1.02	1.00 to 1.07	0.539	0.98	0.93 to 1.02	0.298	0.96	0.92 to 1.01	0.131
BMI	0.93	0.78 to 1.10	0.379	1.10	1.00 to 1.27	0.197	0.99	0.88 to 1.10	0.810
Diabetes	3.00	0.47 to 19.0	0.227	4.60	0.24 to 90.2	0.163	1.63	0.16 to 16.3	0.675
Smoking	3.04	0.54 to 17.2	0.191	0.22	0.04 to 1.19	0.065	0.61	0.15 to 2.45	0.581
Alcohol disorder	1.17	0.20 to 6.77	0.861	0.34	0.08 to 1.44	0.133	0.70	0.16 to 2.95	0.622
CCI	1.89	1.16 to 3.07	**0.011***	1.01	0.63 to 1.62	0.952	0.87	0.57 to 1.34	0.532
MVinjury	1.98	0.39 to 10.0	0.401	3.50	0.65 to 18.9	0.130	0.77	0.20 to 3.01	0.707
Open fracture	1.64	0.27 to 9.98	0.591	2.97	0.63 to 14.0	0.161	2.25	0.51 to 10.0	0.282
Gustilo-Anderson Classification	0.89	0.44 to 1.78	0.739	1.41	0.75 to 2.64	0.282	1.20	0.66 to 2.17	0.549
Polymicrobial	0.12	0.01 to 2.23	0.058	0.11	0.02 to 0.50	**0.002***	0.70	0.16 to 2.95	0.622
DTT pathogen	1.02	0.05 to 22.1	0.533	2.09	0.09 to 47.0	0.372	0.41	0.02 to 7.11	0.527
Consolidation at STR	0.28	0.03 to 2.51	0.231	3.33	0.37 to 30.3	0.263	0.39	0.08 to 1.79	0.214
Debridements before STR	1.21	0.81 to 1.82	0.359	0.76	0.53 to 1.08	0.125	0.75	0.52 to 1.07	0.108
Time from FRI to STR	1.00	1.00 to 1.00	0.919	1.00	1.22 to 1.01	0.617	1.00	1.00 to 1.01	0.618
ASA class ≥ 3 at STR	2.07	0.42 to 10.2	0.366	0.82	0.21 to 3.27	0.779	0.24	0.06 to 0.98	**0.040***
Fracture fixation after STR	3.00	0.33 to 27.0	0.307	0.43	0.50 to 4.07	0.454	2.25	0.42 to 12.0	0.335
Operative time	1.00	1.00 to 1.01	0.163	1.00	0.99 to 1.00	0.155	1.00	1.00 to 1.01	0.353
Free STR	0.93	0.19 to 4.61	0.933	1.54	0.39 to 6.11	0.536	0.76	0.20 to 2.93	0.692
Flap tissue†	2.19	0.40 to 12.0	0.360	1.84	0.33 to 10.3	0.482	2.14	0.39 to 11.8	0.375
Perioperative revision of anastomosis	1.06	0.04 to 27.1	0.567	0.17	0.01 to 2.37	0.154	0.12	0.01 to 1.73	0.084
Primary flap failure				1.85	0.19 to 17.9	0.590	2.12	0.22 to 20.3	0.508

* Statistically significant.
† Osteocutaneous flap excluded.OR, odds ratio; CI, confidence interval; BMI, body mass index; CCI, Charlson Comorbidity Index; MV, motor vehicle; DTT pathogen, difficult-to-treat pathogen; FRI, fracture-related infection; ASA, American Society of Anesthesiologists.

Bacteriology and course of infection

In 55 (55/58) patients, a disease-causing microorganism could be detected; in the remaining three (3/58) patients, infection was diagnosed only by the presence of a fistula. The most commonly found pathogens in patients were *Staphylococcus aureus* (20/58), coagulase-negative staphylococci (20/58) and Enterobacteriales (20/58) (Table 5). In 18 (18/58) patients, the infection was polymicrobial.

Neither the time span between FRI and STR was a risk factor for persistent or recurrent infection ($p = 0.618$, odds ratio (OR) 1.00, 95% confidence interval (CI) 1.00 to 1.01), nor the number of debridements between FRI and STR ($p = 0.108$, odds ratio (OR) 0.75, 95% confidence interval 0.52 to 1.07) (Table 4).

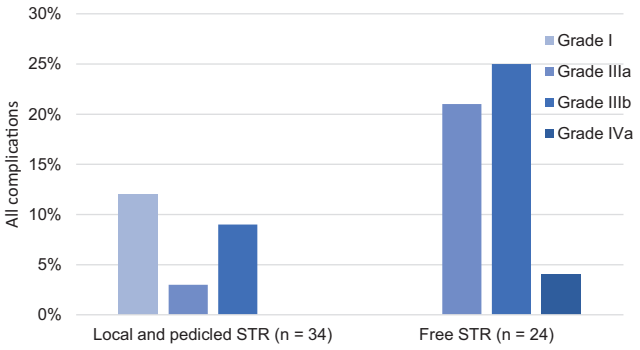

Fig. 5. Complications according to the Clavien-Dindo classification (13) in local and pedicled soft-tissue reconstruction (STR) vs. free STR.
STR: soft-tissue reconstruction.

Table 5
Number of patients with microbiological results from tissue samples.

Pathogen	Patients, $n = 58$
Staphylococcus aureus	20
Coagulase negative staphylococcus	20
Enterobacteriales*	20
Anaerobes	10
Streptococcus spp.	5
Enterococcus spp.	3
Pseudomonas aeruginosa	2
Corynebacterium spp.	1
Other	6
Negative	3

*_Enterobacter_ spp., _Escherichia coli_, _Klebsiella_ spp., _Proteus_ spp., _Serratia_ spp.

Within the 9-months follow-up interval absence of a recurrent infection, which was defined as a cure, was observed in 31 of 43 patients. American Society of Anesthesiologists (ASA) class 3 or higher ($p = 0.040$, OR 0.24, 95% CI 0.06 to 0.98) was a significant risk factor for persistence or recurrence of infection (Table 4).

Overall orthoplastic outcome

As described above, seven flap failures were documented. All these primary STR failures (partial or total flap failure) were successfully reconstructed secondarily. Nine months after successful STR, missing fracture consolidation was seen in 11 patients and recurrent infection in 12 patients. In five patients there was a combination of missing fracture consolidation and recurrent infection, translating into a total of 18 failed treatments out of 43 patients completing the follow-up. In only one patient, there was an overlap in failure of primary STR, failure of fracture consolidation and failure of infection eradication (Fig. 2, bottom, orange circles displaying intercepts of failures). Primary flap failure was neither a risk factor for compromised fracture consolidation ($p = 0.590$, OR 1.85, 95% CI 0.19 to 17.9) nor for recurrence of infection ($p = 0.508$, OR 2.12, 95% CI 0.22 to 20.3) (Table 4).

A comprehensive detailed list of the orthoplastic failure patients is provided in the appendix (Supplementary material I).

Discussion

In our cohort of 145 patients with lower leg FRI a considerable number of 40% ($n = 58$), needed STR over the fracture site. When primary STR failed, secondary STR was performed successfully and primary flap failure was neither a risk factor for compromised fracture consolidation nor for recurrence of infection. Because these patients often had multiple previous operations, the soft tissues around the FRI site may have been scarred, fibrotic, oedematous and tight. Therefore, the orthoplastic surgeons should be experienced, skilled and have a low threshold for soft-tissue augmentation. Despite successful STR, the overall long-term failure rate with missing fracture consolidation or recurrence of infection was high (18/43).

The scarce literature on this topic demonstrates a comparable rate of STR around FRIs seen at our institution [20]. Sixteen (16/58) patients needed surgical revision due to FRC, including a flap failure rate of seven patients (7/58), without any difference between local/pedicled and free flaps. These numbers are in line with data published for free-flap STR of the lower leg, in which a flap failure rate of 8% is reported [21], although our failure rate also included pedicled flaps. As reported previously, the outcome of STR was not dependent on flap type (local, regional, distant), flap tissue (fasciocutaneous, muscle, musculocutaneous) or method of transfer (pedicled, free), as has been reported previously [21,22]. But a high Charlson Comorbidity Index Score was a significant risk factor for flap failure ($p = 0.011$). Patients with ASA class 3 or higher ($p = 0.040$) showed significantly more persistent or recurrent of infections.

In our cohort, all primary STR failures were seen within the first 19 days, no long-term STR failures were seen after this timepoint. In particular, free flaps were considered reliably revascularized after one week, as the intima of the pedicle should have grown over the suture material of the microvascular anastomosis by then, normalizing the risk of thrombosis. Patients were usually gradually mobilized two weeks after STR. Hence, any wound healing problem would have been noticed by then. From this experience, STR may be considered successful after three weeks. However, this proposition needs to be internally and externally validated for inter-institutional comparison.

Previous reports have shown that the time span (i) from injury to first debridement, (ii) from admission to first debridement or (iii) from first debridement to STR is not a risk factor for developing FRI [23]. Our study adds further data to this body of evidence, indicating that neither the time span between FRI and STR nor the number of debridements between FRI and STR is a risk factor for STR failure, compromised fracture union, or recurrence of infection. Although the optimal time interval between FRI and STR is still debated [20,24,25], we prefer early STR with a minimal number of previous debridements. The only significant single risk factor found for persistent or recurrent infection was polymicrobial infection, which is in line with the findings of previous studies [26].

Despite successful STR, a high failure rate of our long-term composite outcome was observed at 9-months follow up in comparison with literature [20]. The nonunion rate was observed in 11/43 and a recurrent infection rate was diagnosed in 12/43 patients. With five overlapping patients, this resulted in a combined composite failure in 18/43 patients. These numbers are comparable to some reports [21,26] and significantly higher than others [27,28], which may be partially attributed to the fact that our study included all recurrent infection over time as failures rather than only the current infection status at a defined final follow-up time point [28]. Three (3/42) patients underwent limb amputation, which was comparable to the 6% reported by Cho et al. [21] and the 7.7% by Chadayammuri et al. [26].

The most important limitations of this study are the retrospective study design and the relatively short follow-up interval. An international expert group recommended a minimum follow-up of one year after cessation of FRI therapy [8]. The follow-up time point was set in this study at 9-months since after this times-

pan fracture consolidation should be detectable in the lower leg and fracture nonunion is commonly diagnosed by then [17]. Some cases may have healed after a longer follow-up period, leading to a lower failure rate. However, at 9-months a compromised fracture consolidation can be reliably diagnosed. One of the main outcome measures of the study was to analyse if flap failure is a risk factor for compromised fracture healing. With a 9-months follow-up this question can be answered. Furthermore, the overall low number of cases that required STR and developed complications limit the significance of risk factor analysis. A multitude of factors that contributed to a sum could have led to a poor long-term outcome, whereas most factors alone did not prove significant.

Previous studies demonstrated the best possible outcome when patients with FRI were treated at a specialized bone and joint infection unit [29,30]. At our institution, since the implementation of a bone and joint infection centre in October 2019, all patients with FRI and possibly in need of STR are now clinically assessed preoperatively by an orthopaedic limb reconstruction surgeon specializing in bone infection, a reconstructive plastic surgeon and an infectious diseases physician simultaneously. Imaging is reviewed by a musculoskeletal radiologist and vascular status by an angiologist. Interaction between various specialists as part of an orthoplastic treatment concept thereby allows a simultaneous multidisciplinary approach while the patient is located in one institution [2]. Furthermore, FRCs (e.g. free flap thrombosis, uncontrolled infection) and non-FRCs (e.g. stroke, cardiac infarction, sepsis) can be treated without delay. Therefore, a continuous orthoplastic service that includes 24/7 microvascular backup is mandatory, as management with an on-demand consultation service alone is insufficient.

Conclusion

This orthoplastic study is among the few reports to present both plastic surgical and orthopaedic long-term follow-up data in the field of FRI. Despite the retrospective nature of the study, relevant conclusions can be drawn: In our population, a considerable number of patients with FRI required STR. This patient subgroup is complex and rich in complications. It appears that secondary STR should be performed as primary flap failure was neither a risk factor for compromised fracture consolidation nor for recurrence of infection. We propose monitor these patients closely for three weeks after STR, as by then, STR can be considered successful. However, despite good STR outcome, the long-term composite outcome showed a high rate of compromised fracture consolidation and recurrent infections.

Funding statement

This research received no specific grant from any funding agency in the public, commercial or not-for-profit sectors.

Declaration of Competing Interest

All authors declare that they have no financial or personal relationships that could influence this study.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.injury.2021.07.022.

CRediT authorship contribution statement

Seraina L.C. Müller: Visualization, Data curation, Formal analysis, Writing – original draft. **Mario Morgenstern:** Visualization, Formal analysis, Writing – original draft. **Richard Kuehl:** Visualization, Writing – original draft. **Thaddaeus Muri:** Visualization, Data curation. **Daniel F. Kalbermatten:** Writing – original draft. **Martin Clauss:** Visualization, Formal analysis, Writing – original draft. **Dirk J. Schaefer:** Writing – original draft. **Parham Sendi:** Visualization, Formal analysis, Writing – original draft. **Rik Osinga:** Visualization, Data curation, Formal analysis, Writing – original draft.

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