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Microvascular Reconstruction in Ballistic Injuries of the Maxillofacial Region

Michael Maurer, MD, DDS*
Katja Himmelstoss, MD, DDS*
Nura Ahmad, MD†
Mathias Fiedler, MD, DDS*
Johannes G. Schuderer, MD, DDS*
Johannes K. Meier, MD, DDS*
Torsten E. Reichert, MD, DDS*
Tobias Ettl, MD, DDS*

Background: Ballistic injuries to the maxillofacial region pose a major reconstructive challenge due to complex anatomy and the need to restore both aesthetic appearance and essential functions such as speech and swallowing. This study evaluates microvascular reconstruction strategies and associated complications in these injuries.

Methods: A retrospective descriptive study was performed, including patients treated at a level I trauma center during a 10-year period. Inclusion criteria were (1) ballistic injury to the lower face or midface, (2) tissue loss requiring microvascular reconstruction, and (3) complete clinical and radiological documentation. Data collected included demographics, injury characteristics, reconstructive techniques, complications, and microbiological findings.

Results: Nine patients underwent microvascular reconstruction between 2015 and 2025, with a total of 15 free flap procedures performed, including 10 fibula free flaps. One flap loss occurred due to infection 3 months postoperatively. Reconstruction was delayed in 7 cases. War-related injuries and delayed reconstruction were significantly associated with preoperative wound infection and detection of multidrug-resistant Gram-negative (MDRGN) organisms ($P = 0.018$ and $P = 0.023$, respectively). The presence of MDRGN organisms was significantly associated with the occurrence of surgical site infections ($P = 0.016$).

Conclusions: Microvascular free flap reconstruction remains the gold standard for complex maxillofacial ballistic injuries, even under adverse conditions. War-related trauma and delayed reconstruction are strongly associated with infectious complications, particularly involving MDRGN, and should be carefully considered in perioperative management. *(Plast Reconstr Surg Glob Open 2026;14:e8202; doi: 10.1097/GOX.0000000000008202; Published online 15 October 2026.)*

INTRODUCTION

Ballistic injuries to the maxillofacial region have increased in the context of modern armed conflicts, including those in Ukraine, Syria, Afghanistan, and Palestine. In addition, firearm-related injuries due to interpersonal violence and suicide attempts continue to contribute significantly to the overall burden of facial trauma. The management of these injuries poses a particular challenge for reconstructive maxillofacial surgeons due to the frequent presence of extensive tissue defects and the complex anatomy of this region, both from a functional and an aesthetic perspective.

Among US armed forces participating in the conflicts in Iraq and Afghanistan, 26% of war casualties sustained injuries in the field of oral and maxillofacial surgery. Thirty-six percent of the war-related facial fractures involved the mandible, and 19% involved the zygomaticomaxillary complex.[1] Matolinets et al[2] reported a significant increase in maxillofacial injuries in the context of the Russian invasion of Ukraine. Ucak[3] classified 56.2% of facial injuries as severe in a patient cohort recruited from the Syrian war with Injury Severity Scores ranging from 25 to 75. In addition to war-related injuries, there are also gunshot wounds resulting from attempted homicide or suicide. In 2022, nearly 50,000 deaths occurred due to firearm-related injuries in

*From the *Department of Oral and Maxillofacial Surgery, Regensburg University Hospital, Regensburg, Germany; and †Department of Plastic, Hand and Reconstructive Surgery, Regensburg University Hospital, Regensburg, Germany.*

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the United States, with more than half (27,000) resulting from suicide attempts.[4]

In cases of extensive defect injuries, free microvascular flap reconstruction is considered the treatment of choice for restoring aesthetics in the facial region, the ability to ingest food, and speech function.[5,6] Mahri and Rikhotso[7] identified the mandible as the most frequently fractured bone in facial gunshot injuries. For mandibular reconstruction, the fibula free flap (FFF) is primarily used. For bony reconstruction of the maxilla, the fibula is also used among other options.[6]

The Department of Oral and Maxillofacial Surgery at Regensburg University Hospital serves as a tertiary care center responsible for facial gunshot injuries in the region of Eastern Bavaria and is also involved in the treatment of war victims, primarily from Ukraine but also from other conflict zones. This study presents a descriptive analysis of microvascular reconstruction in the management of ballistic injuries to the maxillofacial region, including associated complications.

Takeaways

Question: What factors influence complications in patients undergoing microvascular reconstruction after ballistic injuries to the maxillofacial region?

Findings: In this retrospective case series, wound infections were common and associated with injury context and timing of reconstruction. Patients undergoing delayed reconstruction and those with war-related injuries showed higher infection rates, including multidrug-resistant organisms, which were linked to postoperative complications.

Meaning: Infectious complications are central to the management of ballistic maxillofacial injuries. Careful infection risk assessment, appropriate antimicrobial therapy, and optimal timing of reconstruction are essential to improve outcomes, while microvascular reconstruction remains a reliable option.

PATIENTS AND METHODS

Medical records of patients with ballistic trauma who underwent microvascular reconstruction of the maxillofacial region at Regensburg University Hospital, between 2015 and 2025, were retrospectively assessed. (**See table, Supplemental Digital Content 1**, which displays the baseline data, **https://links.lww.com/PRSGO/F352**.) Patients with incomplete clinical and radiological pre- and postoperative documentation were not included. In addition to demographic data, the mechanism of trauma (gunshot, shotgun, shrapnel, explosion, or drone attack) was recorded, as well as whether the injury occurred in the context of armed conflict or with criminal or suicidal intent. Based on pre-, intra-, and postoperative photographic documentation, clinical notes, and preoperative imaging using computed tomography of the facial skeleton and panoramic radiographs, the locations of hard- and soft-tissue injuries were documented. Osseous injuries were further classified according to the Bénateau classification[8] (Fig. 1). The time interval between trauma and reconstructive surgery, as well as the number and type of microvascular reconstructions, were recorded. The timing of definitive reconstruction was defined as early if it was performed during the initial hospital stay after the trauma, or delayed if reconstruction took place during a second or later hospital admission.[9] In addition, the preoperative infection status of the wounds and postoperative infection-related complications were assessed. The required antibiograms were obtained using wound swab samples. Surgical site infection (SSI) was defined according to the Centers for Disease Control and Prevention guidelines. These include infection occurring within 30 days postoperatively and at least one of the following: purulent drainage, positive microbiological culture, clinical signs of infection (pain, swelling, erythema, or warmth), wound dehiscence, or diagnosis by the treating surgeon.[10,11] Furthermore, pre-, intra-, and, if applicable, postoperative wound swabs were reviewed with regard to the respective spectrum of pathogens, and antibiotic therapy was documented. Statistical analyses were performed using cross-tabulations and the Fisher exact test. A P value of less than 0.05 was considered statistically significant. Data analysis was conducted using IBM SPSS Statistics, version 31.0.2.0.

RESULTS

Base data are shown in Supplemental Digital Content 1 (**https://links.lww.com/PRSGO/F352**). A total of 9 patients with a median age of 33.22 ± 10.10 years at the

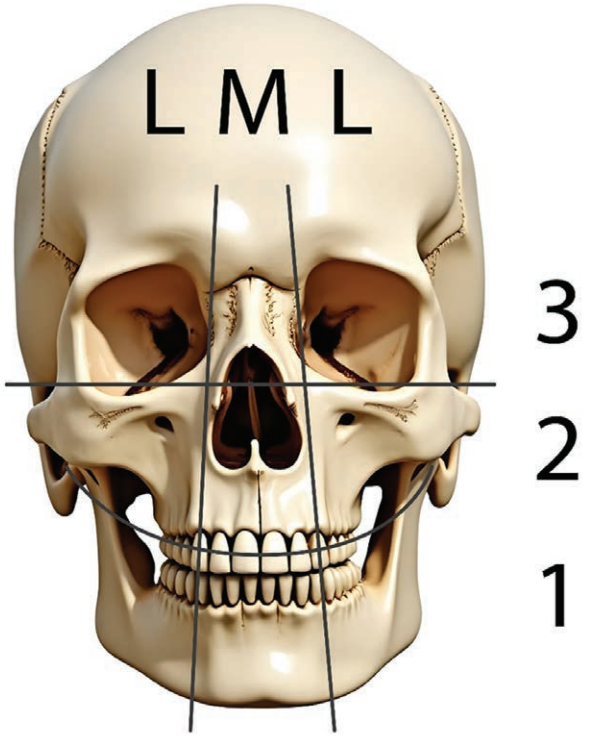


Fig. 1. Benateau classification[8]: localization of bony facial injuries. L, lateral; M, medial; 1, mandible; 2, lower midface; 3, upper midface.

date of the trauma and 36.89 ± 12.99 years at the date of the reconstruction were enrolled in this study and have been followed up for periods ranging from 5 months to 2 years. Of the 9 patients, 55.6% of traumas were caused by bullets (n = 5); the other causes were shotgun fire, shrapnel, explosion, and drone attack, each affecting 1 patient. Five patients sustained their injuries in the context of armed conflict, and 2 cases resulted from a suicide attempt (Fig. 2). In 5 cases, the mandible was affected in isolation; in 2 cases, the maxillary complex or midface was involved; and in a further 2 cases, both the mandible and the zygomaticomaxillary complex were affected. The corresponding soft-tissue injuries were strictly lateral in 3 cases, central in 5 cases, and centrolateral in 1 case. In 6 cases, conventional fracture reduction with osteosynthesis was performed immediately after trauma, whereas in 2 cases, only the soft-tissue injuries were treated. For defect reconstruction, a total of 10 FFFs (Figs. 3, 4), 3 radial forearm flaps, and 2 microvascular iliac crest free flaps were used. In 7 cases, reconstruction was delayed, defined as a time interval of at least 2 months and not performed during the initial medical treatment or hospital stay following trauma. One case, in which reconstruction was performed approximately 29 years after trauma, was not classified as delayed, as the long interval had resulted in a largely functionally stable condition, and the infection-prone phase in the early months after trauma had long been overcome. (**See figure, Supplemental Digital Content 2**, which displays a patient with a midfacial defect 29 years after a gunshot injury. A, Clinical presentation. B, Preoperative computed tomography. C, Computer-aided design/computer-aided manufacturing planning of the reconstruction with FFF. The gaps visible between the 3 fibula segments are the result of the oblique osteotomies required to achieve the desired mandibular contour

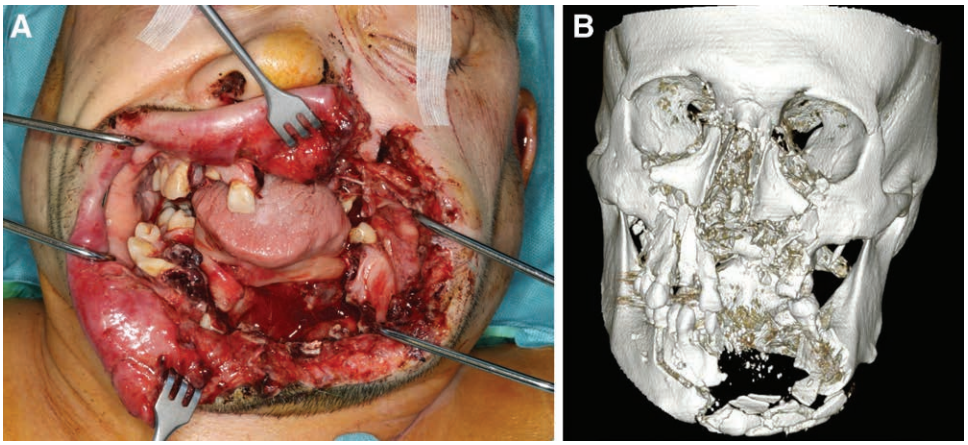


Fig. 2. Severe facial ballistic injury involving midface, maxilla and mandibula. A, Clinical presentation of a patient with a gunshot wound following a suicide attempt. B, Corresponding computed tomography scan.



Fig. 3. Orthopantomogram after reconstruction of the maxilla and mandible with FFFs and open reduction and internal fixation of the midfacial fractures.

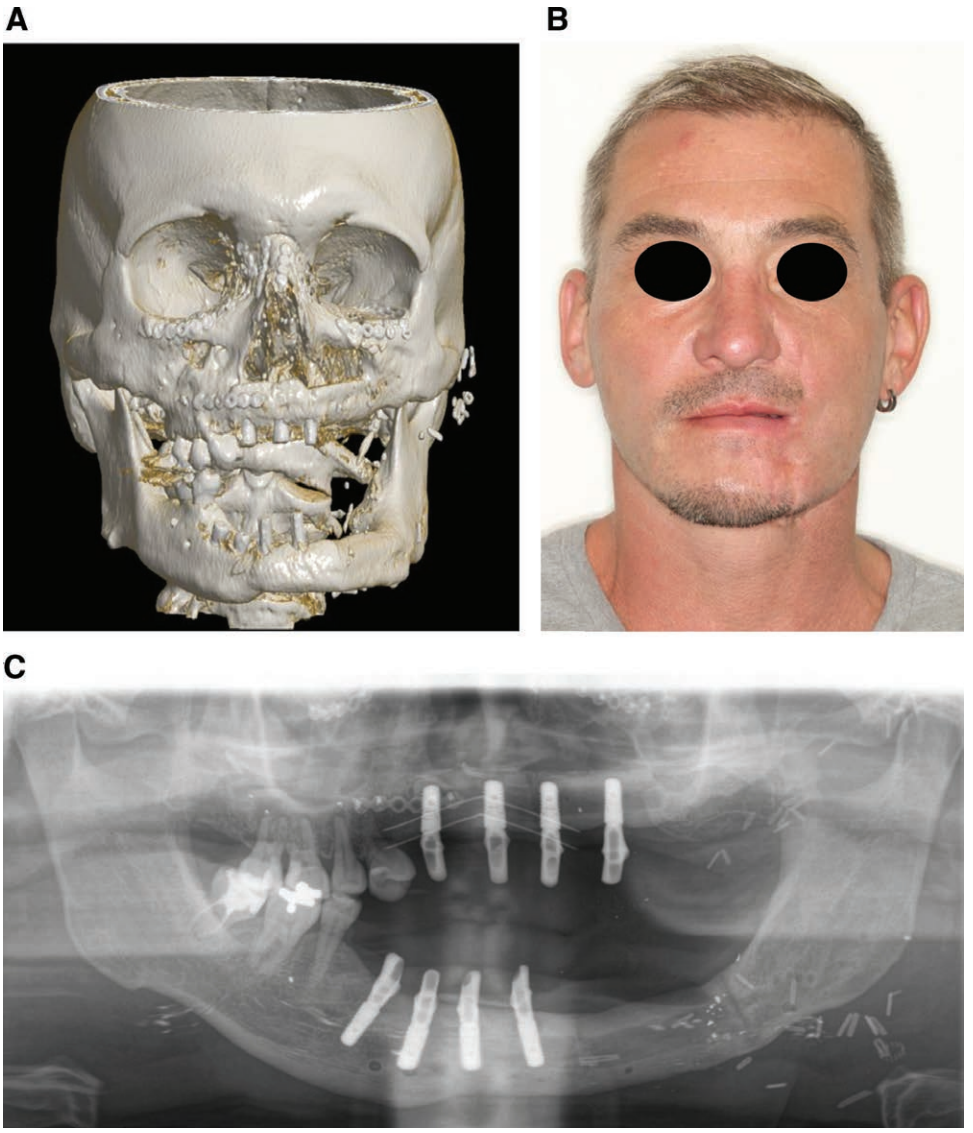


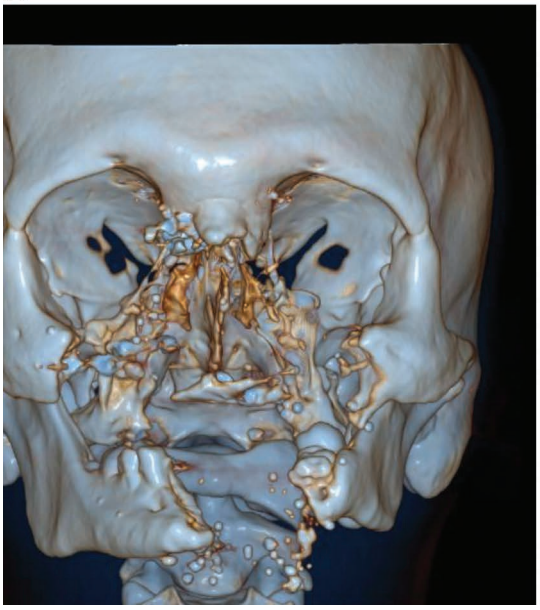
Fig. 4. Patient after hardware removal with well-healed FFFs and insertion of dental implants 1.5 years after the trauma. A, Postoperative computed tomography. B, Clinical presentation. C, Orthopantomogram.

and adaptation to the defect geometry. Small bone wedges had to be resected during flap shaping; however, no substantial bone length was intentionally discarded. D, Postoperative orthopantomogram. E, Orthopantomogram 1.5 years after reconstruction, following hardware removal and insertion of dental implants, **https://links.lww.com/PRSGO/F353**.) The initial hospital stay for reconstructive treatment averaged 33.22 ± 39.96 days. The length of hospital stay was not normally distributed (Shapiro–Wilk test, $P < 0.001$), primarily due to 1 prolonged hospitalization of 138 days. Therefore, hospital stay is reported as the median and interquartile range. The median length of stay was 20 days (interquartile range 16–26 d; range 11–138 d). In 2 cases, reconstruction was completed with a second free flap during a subsequent hospital admission. In 6 cases, wounds were infected before reconstruction. Multidrug-resistant Gram-negative (MDRGN) organisms were detected pre- or intraoperatively in 5 cases and postoperatively in 4 cases. SSI occurred in 4 cases after reconstruction (Table 1). All patients with war-related injuries presented with preoperatively infected wounds. This was a statistically significant association ($P = 0.048$). Six of the 7 patients who underwent delayed reconstruction had preoperative wound infections ($P = 0.083$). Furthermore, 5 of 7 patients who underwent delayed reconstruction had MDRGN detection ($P = 0.167$). Among war-injured patients, MDRGN organisms were detected pre- or intraoperatively in 5 of 5 cases ($P = 0.048$) and postoperatively in 3 of 5 cases ($P = 0.524$). One of the 4 patients with non–war-related injuries had pre- or postoperative wound infection and MDRGN organism detection (Fig. 5). In the delayed reconstruction group, 4 of 7 patients showed postoperative MDRGN

Table 1. Wound Infections/SSI

Patient	Preoperative Infection	War Injury	Preoperative Microbial Spectrum	Intraoperative Microbial Spectrum	SSI After Reconstruction	Postoperative Microbial Spectrum	MDRGN	Initial Antibiotic Therapy	Escalated Antibiotic Therapy According to Antibiogram
1	Yes	Yes	*Streptococcus mitis*	*K. pneumoniae* (4MDRGN), *Morganella morganii, Enterococcus faecium*	Yes	*K. pneumoniae* (4MDRGN)	4MDRGN	Amoxicillin/clavulanic acid	Ceftazidime/avibactam, daptomycin, aztreonam
2	Yes	No	*P. aeruginosa* (4MDRGN)	*Actinomyces odontolyticus*	Yes	*Citrobacter freundii, P. aeruginosa* (4MDRGN)	4MDRGN	Amoxicillin/clavulanic acid	Colistin, meropenem
3	No	No	—	—	No			Piperacillin/tazobactam	Piperacillin/tazobactam
4	No	No	—	—	No			Ampicillin/sulbactam	Ampicillin/sulbactam
5	Yes	Yes	*Staphylococcus aureus* (MSSA), *Serratia marcescens*	*Staphylococcus aureus*	No	—		Meropenem	Meropenem
6	Yes	Yes	*E. cloacae* (3MDRGN), *Staphylococcus epidermidis*	—	No	—	3MDRGN	Amoxicillin/clavulanic acid	Piperacillin/tazobactam, vancomycin
7	No	No	*Staphylococcus aureus*	—	No	—		Piperacillin/tazobactam	Piperacillin/tazobactam
8	Yes	Yes	*Prevotella buccae, Streptococcus mitis, Candida albicans*	*E. cloacae* (3MDRGN)	Yes	*E. cloacae* (3MDRGN)	3MDRGN	Amoxicillin/clavulanic acid	Meropenem
9	Yes	Yes	*Prevotella disiens, Streptococcus mitis*	*P. aeruginosa* (3MDRGN)	Yes	*K. pneumoniae* (4MDRGN)	3 + 4 MDRGN	Amoxicillin/clavulanic acid	Ceftazidime/avibactam, aztreonam/avibactam
Total	6/9 (66.7%)	5/9 (66.7%)			4/9 (44.4%)		3×3MDRGN; 3×4MDRGN		

A



B

Antibiogramm	K1	K2	K3	K4
Ampicillin o. Amoxicillin		R	R	
Amoxicillin/ Clavulanic Acid	R	R	R	S
Piperacillin/ Tazobactam	R	R	R	
Flucloxacillin				S
Cefazolin				S
Cefuroxim i.v.				S
Ceftriaxon o. Cefotaxime	R			
Cefotaxime o. Ceftriaxon		R	S	
Ceftazidime	R	R		R
Cefepime	R	S		
Imipenem	R	S		
Meropenem	R	S		
Ciprofloxacin	R	S	S	
Moxifloxacin	R			
Cotrimoxazole		S	S	S
Clindamycin				S
Gentamicin	R			
Tobramycin	R			
Rifampicin				S

Fig. 5. Patient with a combined defect of the mandible and midface. A, Preoperative computed tomography. B, MRDGN identified in the wound swab from an SSI after delayed reconstruction. K, colony; R, resistant; S, sensitive.

Table 2. Risk Factors for Wound Infections

	War Injury			Preoperative Infection			Pre/Intraoperative MDRGN			Postoperative MDRGN			SSI After Reconstruction		
	Yes	No		Yes	No		Yes	No		Yes	No		Yes	No	
War injury															
Yes		—		5	0	$P = 0.048$	5	0	$P = 0.048$	3	2	$P = 0.524$	3	2	$P = 0.524$
No				1	3		1	3		1	3		1	3	
Delayed reconstruction															
Yes	5	2	$P = 0.073$	6	1	$P = 0.083$	5	2	$P = 0.167$	4	3	$P = 0.444$	4	3	$P = 0.444$
No	0	2		0	2		0	2		0	2		0	2	
MDRGN (pre/intra/postoperative)															
Yes	4	1	$P = 0.206$		—			—			—		4	1	$P = 0.048$
No	1	3											0	4	

detection and developed SSI ($P = 0.444$; $P = 0.444$, respectively). Among patients with MDRGN detection at any time point, 4 of 5 developed SSI ($P = 0.048$) (Table 2).

DISCUSSION

Ballistic injuries to the facial region represent a particular challenge for reconstructive surgeons due to the complex anatomy of this area.[5] In cases of extensive tissue loss or defect-associated fractures, microvascular osteocutaneous flaps are the treatment of choice to restore both function and aesthetics.[6,9,12] The present study focuses on the reconstruction of the mandible and midface using microvascular flaps following ballistic injuries. All included patients were male, with a mean age of approximately 33 years. These demographic findings are consistent with previous studies. For example, Stein et al[9] reported exclusively middle-aged male patients, and Zeidan et al[13] reported 94% male patients with a mean age of 32 years. The average hospital stay for carrying out the reconstruction was 33.22 ± 39.96 days. The prolonged hospitalization was largely attributable to social circumstances rather than medical necessity. In particular, many patients with war-related injuries remained in hospital because they lacked permanent housing in our country. For example, 1 patient had to remain hospitalized for 138 days for this reason. In the majority of cases, the mandible was primarily affected. Kassouf et al[14] likewise reported that the mandible is the most frequently involved bone in patients with facial gunshot wounds requiring surgical reconstruction, likely because injuries to the upper facial region are more often immediately fatal.

All patients in this study presented with extensive bony defects or large areas of pseudarthrosis in combination with soft-tissue loss or scarring requiring microvascular reconstruction. The FFF is considered the most suitable option for mandibular reconstruction.[13,14] In our cohort,

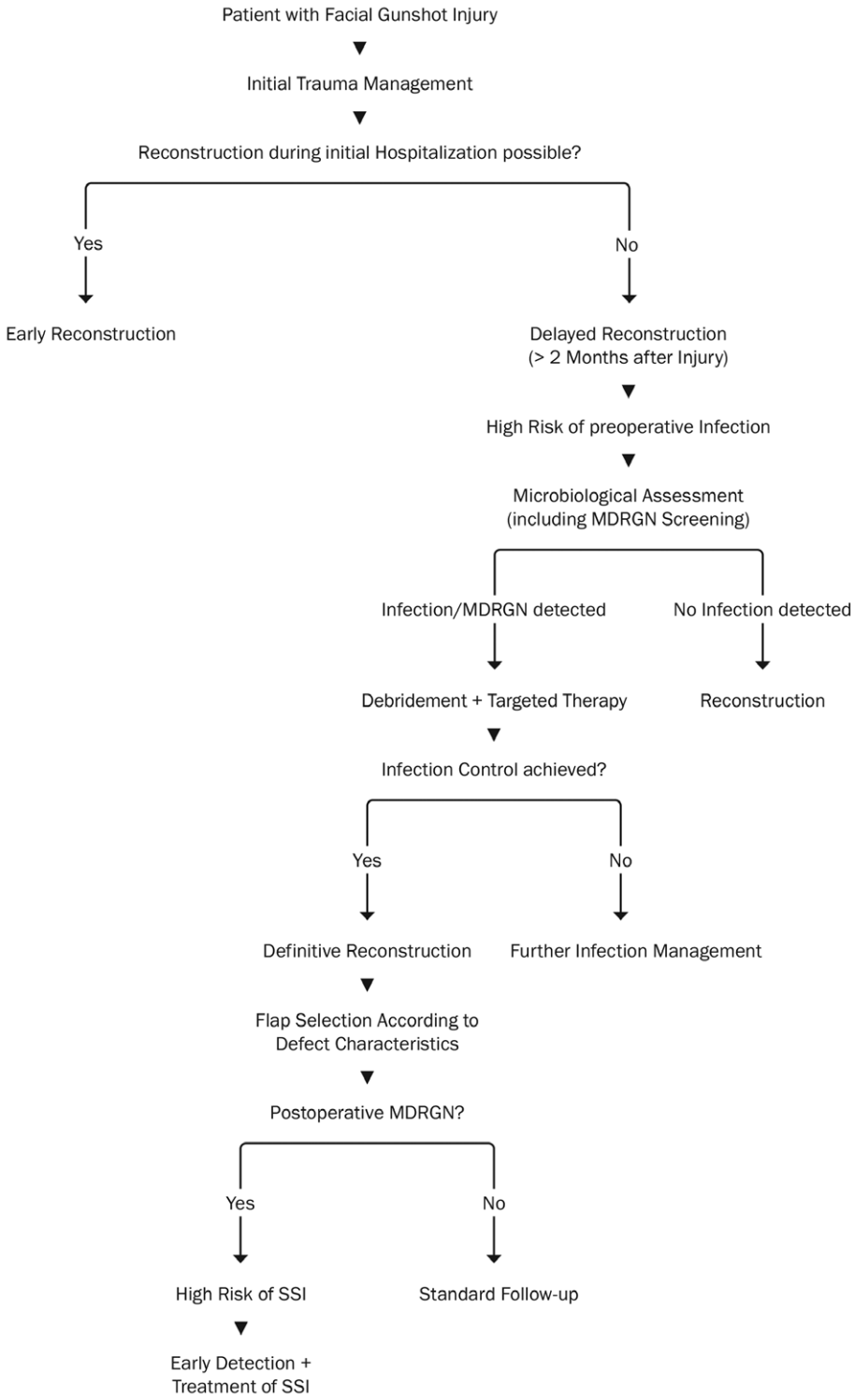


Fig. 6. Proposed treatment algorithm for reconstruction of facial ballistic injuries.

10 FFFs were used in 9 patients, with no flap loss observed. In our opinion, the fibula represents the gold standard for mandibular reconstruction in cases of ballistic injuries. It can also be used for maxillary or midfacial reconstruction, as demonstrated in 2 patients without flap loss. Advantages of the FFF include the substantial length of the bony component with flexible segmentation, a long vascular pedicle, and reliable periosteal and intramedullary blood supply, as well as dimensions that are perfectly suitable for facial reconstruction.[13]

In cases of extensive composite defects involving both bone and soft tissue, particularly with intra- and extraoral

aspects or severe scarring, osteocutaneous flaps may be combined with fasciocutaneous or musculocutaneous flaps.[15] In our cohort, 1 patient required a combination of an FFF and a radial forearm flap for mandibular reconstruction with intra- and extraoral soft-tissue defects. Another patient required 2 FFFs and 2 radial forearm flaps to reconstruct extensive defects of both the mandible and midface. In this patient, the 4 free flaps enabled reconstruction of the nose, oral sphincter, bony midface, and mandible. As a result, facial aesthetics, mouth opening, oral intake, and speech articulation improved to the extent that the patient was able to participate in public life again. We consider the combination of the FFF and radial forearm flap to be well suited for reconstruction of large composite defects and recommend considering it in ballistic injuries. In cases of lip defects, the radial forearm flap can be harvested with the palmaris longus tendon to facilitate restoration of lip competence. It can also be used in midfacial defects involving the nose. The folded radial forearm flap remains a uniquely versatile and resilient option for complex 3-dimensional reconstruction of the lip and nose.[16] In the above-mentioned patient from the cohort, the lip and nose were successfully reconstructed using 2 radial forearm flaps. If additional soft tissue is required, the anterolateral thigh flap can be used as an alternative.

Five of the 9 injuries in this cohort were war-related. Such injuries typically exhibit characteristics that predispose patients to infection, including devitalized tissue; foreign bodies; hematoma; fluid collections; and contamination with bacteria from the patient's skin, the environment, and healthcare facilities.[17] Studies on war-related maxillofacial injuries show that these wounds often receive delayed surgical treatment, as transfer to specialized centers may take up to several weeks.[18] Delayed reconstruction is also associated with a higher risk of infection.[19] However, determining the ideal timing for surgery is difficult. Oren et al[20] recommend reconstructing war-related facial injuries after 2–4 weeks. After this period, revascularization of the tissue is expected to occur, which improves healing and reduces the rate of complications. In the present study, 6 of 9 cases had preoperative wound infections, all of which underwent delayed reconstruction considerably later than 4 weeks. All war-related injuries were preoperatively infected ($P = 0.048$), likely due to the fact that all of them were reconstructed in a delayed manner with stays in multiple healthcare facilities. One non–war-related injury, sustained in a criminal context, also showed multidrug-resistant infection before reconstruction; however, this case had a history similar to that of war injuries, including treatment across multiple healthcare systems and refugee camps. One case involved reconstruction 29 years after trauma. The patient presented with a palatal defect and large oronasal communication, which caused functional impairment but had become stable and infection-free over time. This case differed fundamentally from typical delayed reconstruction and was therefore not classified as such. Petersen et al[19] described *Pseudomonas* spp. and *Klebsiella* spp. as typical pathogens in maxillofacial war injuries. Similarly, in our cohort, *Klebsiella pneumoniae* and *Pseudomonas aeruginosa* were each identified in 2 cases, and *Enterobacter cloacae* in 2 additional cases. All were classified as MDRGN. MDRGN organisms were detected pre- or intraoperatively in all war-related injuries ($P = 0.048$), highlighting this as a characteristic feature of such trauma. Empirical antibiotic therapy, typically with amoxicillin/clavulanic acid, had to be escalated in all war-related cases based on antibiograms to reserve antibiotics, such as ceftazidime/avibactam, aztreonam/avibactam, colistin, vancomycin, or meropenem.

Four patients developed SSI after reconstruction. Three of them had sustained war-related injuries, all had postoperative MDRGN detection, and all underwent delayed reconstruction. We therefore consider these 3 factors to be major contributors to infectious complications. In 1 case, persistent infection with 4MRGN *Klebsiella* led to flap loss 3 months postoperatively. Overall, 14 of 15 microvascular flaps (93.3%) were successful. This study demonstrates that microvascular reconstruction remains the treatment of choice for extensive defects caused by ballistic injuries, even under unfavorable infectious conditions. Notably, in 1 war-related case with delayed reconstruction, initial treatment with the reserve antibiotic meropenem seemed to prevent postoperative SSI. Although this observation may suggest a potential benefit of targeted antibiotic therapy in selected high-risk patients, it is based on a single case and should therefore be interpreted with extreme caution.

LIMITATIONS

The retrospective design of the study is inherently associated with potential information bias. The sample size of 9 patients is very small, similar to that in most studies on this topic, which limits the reliability of the conclusions drawn from the study. Due to the limited sample size and heterogeneity of injury patterns, it is difficult to establish a standardized algorithm for the management of substantial maxillofacial ballistic injuries. The small sample size of 9 patients and multiple subgroup analyses reflect the rarity of the condition; therefore, the statistical analyses and P values should be interpreted with caution. Several conclusions currently seem stronger than the data support. The hypothesis-generating nature of the findings should explicitly be emphasized. This highly heterogeneous cohort with respect to mechanism of injury, timing, anatomical involvement, prior treatment history, and reconstructive strategy substantially limits the external validity of the results.

CONCLUSIONS

In nonlethal facial ballistic injuries, the mandible was the most frequently affected facial bone. Microvascular reconstruction, particularly with the FFF, proved to be a reliable treatment option with a high success rate. War-related injuries and delayed reconstruction were associated with increased rates of wound infection and MDRGN detection, emphasizing the importance of infection assessment and targeted antimicrobial management before definitive reconstruction (Fig. 6).

Michael Maurer, MD, DDS
Department of Oral and Maxillofacial Surgery
Regensburg University Hospital
Franz-Josef-Strauss-Allee 11
93049 Regensburg, Germany
E-mail: michael.maurer@ukr.de

DISCLOSURE

The authors have no financial interest to declare in relation to the content of this article.

PATIENT CONSENT

Written informed consent for publication of patient data and clinical results was obtained.

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ETHICAL APPROVAL

Ethical approval was obtained from the ethics committee of Regensburg University (approval no.: 26-4597-104).

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