Foot and Ankle Surgery xxx (xxxx) xxx–xxx

Contents lists available at ScienceDirect

Foot and Ankle Surgery

journal homepage: www.journals.elsevier.com/foot-and-ankle-surgery

Quality of life after fracture-related infection of the foot

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ARTICLE INFO

Article history:
Received 7 April 2022
Received in revised form 2 August 2022
Accepted 14 August 2022

Keywords:
Fracture-related infection
Quality of life
Psychological outcome

ABSTRACT

Background: Fracture related infection (FRI) of the foot is a serious hazard. Despite successful therapy, the physiological and psychological involvement seems to be high. Therefore, we aim to analyze the impact of an FRI of the foot on the quality of life after successful surgical therapy and infect eradication.
Methods: In total, 25 patients from two German hospitals treated for FRI of the foot between March 2011 to January 2020 were retrospectively included. Quality of life was assessed by the German Short Form 36 (SF-36) and the EuroQol five-dimension three-level questionnaire (EQ-5D) as well as the ICD-10 based psychological symptom rating (ISR), and compared to a norm obtained from the general population of Germany.
Results: 3.0 years (range 0.7–7.9 years) following final surgery after fracture-related infection of the foot, the mean physical health component score (PCS) of the SF-36 was 35.6 ± 12.3, and the mean mental health component score (MCS) of the SF-36 reached a value of 41.3 ± 12.9. Both values were significantly lower than in the general population of Germany ($p < .019$). The mean scores of the ISR of the cohort crossed the threshold of mild symptom burden in total, as well as for the subscales depression and somatization. The mean EQ-5D VAS rating (62.1 ± 18.6) and the EQ-5D index value (0.66 ± 0.27) were significantly lower in comparison to a score of 72.9 ± 1.0 and 0.88 obtained from an age-matched reference population ($p < .01$).
Conclusion: FRI of the foot represents a major burden for the patient. Physical and mental well-being of affected patients is restricted albeit successful treatment in terms of infect eradication and bone union has been achieved after a mean follow-up of 3.0 years. A patient-centered treatment approach focusing on improvement of quality of life during and after treatment is therefore warranted.

1. Introduction

Implant related infection is a major complication in trauma surgery after reduction and internal fixation of a fracture utilizing metallic devices, and therefore negatively affecting both the patient and his immediate family [1–3]. Beside medical and social impact, the financial burden should not be underestimated as direct healthcare costs for patients with surgical site infections were calculated to be nearly twice as high ($108,782 vs. $57,418) compared to non-infected patients [4]. In addition, the mortality risk is considerably increased in patients with surgical site infection, with a 60-year-old being equivalent to that of an 80-year-old in the general population [5].

Despite great clinical significance, the definition of implant related infections after fracture has been inconclusive for a long time. Thus, a group of experts of the AO Foundation recently defined criteria for diagnosis of fracture related infection (FRI), giving a list of confirmatory and suggestive criteria [2]. According to Metsemakers et al., the presence of a fistula or wound defect extending to the implant or the adjacent bone, the accumulation of pus in this area, the detection of microorganisms in the culture (in at least 2 samples of the affected anatomical area or the implant), or the histopathological detection of microorganisms are reliable confirmation criteria. Supportive evidence is provided by the general signs of inflammation, such as redness, swelling, pain, or temperature increase in the area of the suspected infection as a suggestive criterion. Besides, radiological parameters such as sequestration, delayed/non-

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https://doi.org/10.1016/j.fas.2022.08.005
1268-7731/

union, lysis zones, or signs of implant loosening may indicate an FRI [2]. Thus, better interpretation and comparability of clinical studies as well as diagnostic and treatment on established evidenced-based algorithms should be investigated.

In this regard, limited data is available for foot fractures and fracture-related infection. Recently, comparable to the U.S. [6], a 14 % increase in fracture incidence could be recorded in Germany between 2009 and 2019. Regarding foot fractures, the incidence change was mainly due to a fracture increase of 28 % of the ossa tarsi, while fractures of the calcaneus were reduced by 16 % [7] demonstrating that approximately two-thirds of all foot fractures affect the forefoot [8]. Mainly falls (> 60 %), fatigue fractures ("bone just broke" 10.5 %) but also car accidents (3.1 %) were described to cause foot fractures [9] While low-energy trauma usually result in isolated bony fractures that quickly heal, high-energy trauma frequently generates significant soft tissue damage which represents a major risk factor for subsequent complications [9–11]. However, the underlying cause of post-traumatic and implant-associated infections is of multifactorial nature, whereby infections after closed fractures of the foot occur in 1–4 % and after an open fracture in 9,6 % (Gustilo-Anderson type I) to 37,5 % (Gustilo-Anderson type IIIC) of the cases [11–17]. In Germany, the incidence was calculated as 10.7 cases per 100,000 inhabitants in 2018 [3].

The success rate after surgical intervention of the FRI is reported to be 85–93 %. However, 6–9 % of the patients get a re-infection, and 3–5 % require an amputation of the affected limb [18]. We previously were able to demonstrate, that quality of life is substantially lower in patients undergone successfully treatment of FRI of the long bones [1]. For FRI of the foot, quality of life assessment after successful FRI treatment has not been performed, which might be due to underestimated impact of FRI on quality of life compared to FRI when present at the long bones.

Therefore, the purpose of this study was to determine clinical outcome in terms of bone consolidation and infect eradication as well as the physical health state and psychological wellbeing of patients treated for FRI of the foot.

2. Material and methods

2.1. Patients

Patients treated for FRI of the foot in two level 1 trauma centers in Germany between March 2011 to January 2020 were retrospectively included into the study. To cover all patients, an IT query was performed according to the ICD 10 codes "S92.0- S92.3, calcaneus fracture, talus fracture, other tarsal bone fracture, metatarsal bone fracture" and "T84.6, infection and inflammatory reaction due to internal fixation device". Study participation was irrespective of age and sex. Patients with multiple fractures or other comorbidities were expelled to rule out a bias due to further injuries. A total of 33 patients could be identified, whereof 2 patients were reported to be dead and therefore excluded. Thus, the questionnaire was sent to 31 patients by post. The completed questionnaire was returned in 25 cases, resulting in a drop-out rate of 19.4 %. Informed consent was obtained from all individual participants included in the study. All patients included were surgically treated for FRI between 2011 and 2020. Patient characteristics, clinical records and radiographs were retrospectively retrieved from the hospitals electronic patient files system. FRI was verified according to the definitions of the FRI consensus group published in 2018 [2]. Achieved bone consolidation was determined with an evaluated RUST score > 10 [19]. Non-union was defined as no fracture consolidation within six months [20]. The study was approved by the institutional ethics committees of the University Regensburg, Germany and the University Tuebingen, Germany, according to the Helsinki Convention University Regensburg: file number : 20–1681–104; University Tuebingen: file number 240/2021BO2).

2.2. Quality of life assessment

Patient-related outcome and quality of life was assessed using the German Short-Form 36 (SF-36) and EQ-5D-3L scores as well as an ICD-10-based symptom rating (ISR) [21,22], which were sent by post. The latter is an inventory frequently used in psychosomatic anamnesis. It consists of 29 items and covers various mental syndromes with subscales for depression, anxiety, obsessive/compulsive disorders, somatoform disorders and eating disorders [23]. The EQ-5D-3L is a well-established generic quality of life instrument developed by the EuroQol group comprising five questions with 3 levels each concerning the functional domains mobility, self-care, everyday life activities, pain/discomfort and anxiety/depression [24]. The items were converted into a single EQ index value using German norm data weights [25]. Additionally, the EQ-5D was evaluated using the visual analog scale (VAS) method [26]. The widely used SF-36 health survey captures the general health status with 36 questions in eight functional domains: physical function, role physical, bodily pain, general health, vitality, social function, role emotional and mental health. Summary scores for the physical and mental component were calculated using normative data from a German national health interview and examination survey conducted in 1998 with 7124 participants [27]. Quality of life scores were compared to normative data [27,28].

Data was analyzed using SPSS statistics version 24.0 (IBM, SPSS Inc., Armonk, NY). Descriptive statistics were calculated for all variables. Continuous variables were expressed as the mean and standard deviation. For comparisons between continuous variables independent t-tests were performed after determining the distribution was appropriate for parametric testing by Levene's test. Level of significance was set at $p < .01$.

3. Results

In total, twenty-five patients (7 women, 18 men; mean age 55.5 ± 12.8 years) were included in the analysis (Table 1). Seven patients (28.0%) were smokers, and eight patients (32.0 %) reported to be former smokers. One patient (4.0 %) initially had an open fracture, classified as Gustilo-Anderson type IIIa. The mean ASA score was 1.5 ± 0.9 (range 0–3). In all patients infect eradication was achieved. Eight patients (32.0 %) received an arthrodesis of the ankle joint, an amputation was performed in two patients (8.0 %). In nine cases (36.0 %) a non-union was developed. A successful bone consolidation appeared in 15 cases (60.0 %); with one patient (4.0 %) having recently undergone an arthrodesis and therefore, the healing process is ongoing. The mean follow-up time was 3.0 years (range 0.7–7.9 years).

The mean physical health component score (PCS) of the SF-36 was 35.6 ± 12.3, and the mean mental health component score (MCS) of the SF-36 reached a value of 41.3 ± 12.9. In comparison with aged-matched normative data from Germany, patients scored lower in the physical health component (PCS_{Norm}= 45.7 ± 9.4, $p < .001$) as well as in the mental health component of the SF-36 (MCS_{Norm} = 51.0 ± 9.2, $p < .001$), respectively (Fig. 1).

The subdomain analysis of the normative data resulted in mean values of 50.9 ± 7.1 for physical function, 33.0 ± 1.9 for physical role, 42.2 ± 1.8 for bodily pain, 57.0 ± 5.8 for general health, 45.4 ± 4.6 for vitality, 60.5 ± 2.3 for social functioning, 57.3 ± 1.5 for emotional role and 61.8 ± 6.0 for mental health (Fig. 2). Hence, the results of the study group reached 63.3 % for physical function (80.43 ± 20.9, $p < .01$), 43.3 % for physical role (76.3 ± 34.9, $p < .01$), 69.2 % for bodily pain (61.0 ± 25.3, $p < .01$), 92.0 % for general health (62.0 ± 17.4, $p < .01$), 76.1 % for vitality (71.3 ± 17.5, $p < .01$), 71.3 %

Table 1
Patient characteristics.

Age (years)	Sex	Anatomical localization	Non-union	Treatment	Fracture consolidation
33	male	Calcaneus	No	1-staged	Yes
51	male	Calcaneus	Yes	Arthrodesis	No
53	male	Os naviculare	No	DAIR	Yes
63	male	Calcaneus	No	Arthrodesis	Yes
51	female	Calcaneus	No	1-staged	No
54	female	Calcaneus	Yes	Arthrodesis	No
55	male	Lisfranc Fx	No	Amputation	No
57	male	Calcaneus	Yes	Arthrodesis	No
68	male	Calcaneus	No	2-staged	No
68	male	Calcaneus	Yes	2-staged	No
77	male	Calcaneus	No	Arthrodesis	Yes
55	female	Tarsal Fx	Yes	Arthrodesis	Yes
56	male	Lisfranc Fx	No	Multiple staged	Yes
65	female	Lisfranc Fx	Yes	Arthrodesis	Yes
59	male	Calcaneus	Yes	Amputation	No
32	female	Calcaneus	Yes	1-staged	Yes
75	male	Calcaneus	Yes	1-staged	No
30	female	Calcaneus	No	DAIR	Yes
61	male	Calcaneus	No	DAIR	Yes
30	male	Talus	No	Arthrodesis	No
54	female	Os metatarsale	No	DAIR	Yes
53	male	Calcaneus	No	2-staged	Yes
58	male	Calcaneus	No	1-staged	Yes
66	male	Lisfranc Fx	No	1-staged	Yes
63	male	Os metatarsale	No	1-staged	Yes

*DAIR = Debridement, Antibiotics, Implant retention

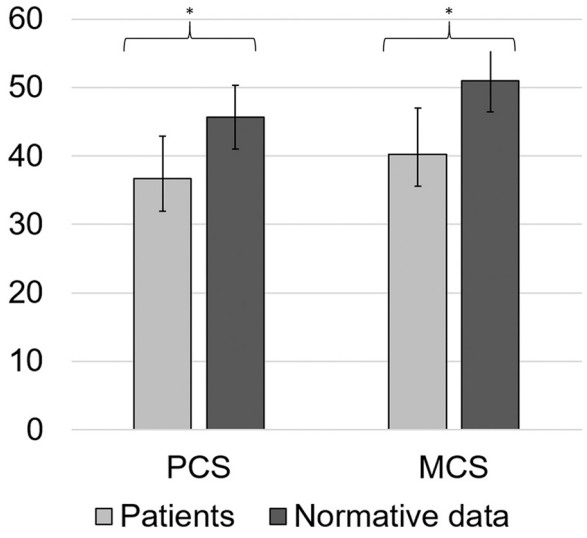

Fig. 1. Mean physical health component score (PCS) and mean mental health component score (MCS) assessed with the SF-36. The results of the fracture-related infection cohort are shown in dark gray. For a comparison the values of the normative data are illustrated in light gray. * p < .01.

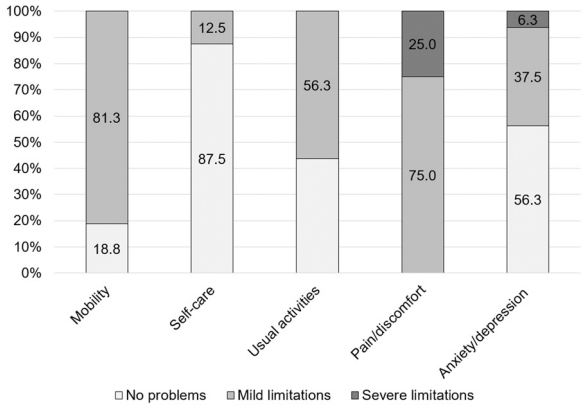

Fig. 2. Subdimension scores for patient-related quality of life assessed with the SF-36. The results of the fracture-related infection cohort are shown in dark gray. For a comparison, the values of the normative data are illustrated in light gray. * p < .01.

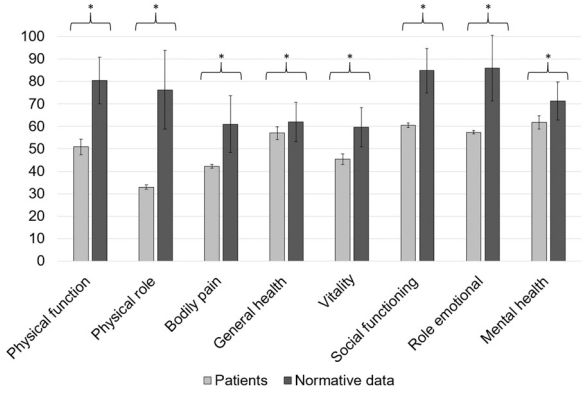

Fig. 3. Mean values of the ISR scores. The black dotted lines depict the border of considered symptom burden.

for social functioning (84.9 ± 19.7, p < .01), 66.7 % for emotional role (86.0 ± 29.2, p < .01) and 86.6 % for mental health (60.8 ± 17.1, p < .01) of the normative values (Fig. 2).

The mean total score of the ISR was 0.74 ± 0.28. The mean ISR subdimension scores reached 1.23 ± 0.31 for depression, 0.86 ± 0.39 for anxiety, 0.50 ± 0.20 for obsessive/compulsive disorders, 0.77 ± 0.18 for somatoform disorders and 0.49 ± 0.13 for eating disorders, respectively (Fig. 3). On average, the cohort crossed the threshold of mild symptom burden regarding the total score, depression and somatization.

The mean EQ-5D VAS rating reached 62.1 ± 18.6 in comparison to a score of 72.9 ± 1.0 obtained from an age-matched reference population (p < .01). The mean EQ-5D index value was 0.66 ± 0.27, which was lower than the age-matched normative value of 0.88 (p < .01). In the subdimensions of the EQ-5D, patients showed limitations, especially concerning pain and discomfort (Fig. 4). In total, 81.3 % of the patients reported problems with mobility (compared to 15.9 % of the German reference), 12.5 % with self-care

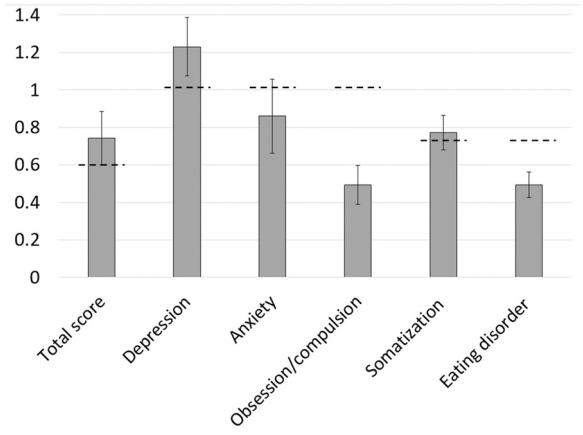

Fig. 4. Percentage of patients showing severe, mild, or no limitations in the EQ-5D subdimensions.

(compared to a norm value of 2.7 %), 56.3 % with usual activities (versus 9.9 %), 100 % with pain/discomfort (compared to 27.6 %) and 43.8 % with anxiety/depression (4.3 % of the normative population).

4. Discussion

The present study investigated the quality of life (QOL) of 25 patients after fracture-related infection of the foot, treated surgically between March 2011 and January 2020 with a mean follow-up time of 3.0 years (range 0.7–7.9 years). QOL was assessed using the EQ-5D-3L, SF-36 and ICD-10-based symptom rating in patients treated after FRI. Compared to an age-matched normative German population, patients who suffered from FRI of the foot had considerably lower scores with respect to quality of life after an average follow-up period of three years, despite infection eradication.

Even though the QOL after FRI is of immense relevance, only a few studies evaluated it yet. Patients with FRI of the foot scored considerably lower on both the mean physical health component score (PCS) and the mean mental health component score (MCS) of the SF-36. Comparable results for PCS were shown for patients with FRI of the long bones, whereas the mental components seemed slightly affected [1]. Recently, it was shown that both, septic and aseptic non-union of the lower extremity likewise adversely affected the physical and mental QOL, due to worse pain and functional impairment [29,30]. The devastating effect on health-related QOL is considered to be worse than suffering a congestive heart failure [29]. Interestingly, this is in line with other findings, since patients with a non-union achieved a very low utility score (range: 0 = death, 1 = perfect health) and thus, lagged behind patients with diabetes, a stroke or acute myocardial infarction [31].

Patients with posttraumatic osteomyelitis of the lower leg had significantly lower scores in the physical, as well as the mental components of the SF-36 compared to a healthy sample from the general population. Alarmingly, even after recovery from post-traumatic osteomyelitis, no significant improvement in SF-36 was achieved [32]. Liener et al. confirmed this in a patient population with osteomyelitis of the upper and lower leg [33]. Lerner et al. emphasized that especially patients with osteomyelitis compared to patients suffering a non-union scored severely worse in “arthritis impact measurement scale” (AIMS), a tool assessing along with dexterity, social role and social function, the risk for depression and anxiety [34].

Monteban and colleagues demonstrated that in patients with fifth metatarsal fracture without a course of infection, both conservative and surgical procedures achieved good results in terms of physical and mental quality of life in a 5-year follow-up study. However, they indicated that impairment of quality of life was related to comorbidities, such as cardiovascular diseases, rather than to the fracture itself [35]. In addition, it was shown that patients surgically treated for calcaneus fracture without any history of FRI, achieved lower results in the SF-36 physical and mental components 2.9 years after the initially surgery than to the general population [36]. Compared to our results, it becomes evident that patients with FRI of the foot obtained lower summary scores in the PCS (FRI: 35.6 ± 12.3 vs. calcaneus fracture: 38.3 ± 11.3) and MCS (FRI: 41.3 ± 12.9 vs. calcaneus fracture: 49.8 ± 11.2) [36]. Thus, it is suggested that foot fractures negatively affect the quality of life and that the patients’ quality of life is further diminished by the additional burden of FRI. Notably, in the presented cohort, eight patients (32.0 %) received an arthrodesis of the ankle joint, whereas an amputation was performed in two patients (8.0 %). Whereas literature on the quality of life after different treatment approaches for FRI is missing, it was shown that quality of life scores after ankle arthrosis had better SF-36 outcomes (PCS 53.7 ± 23.9, MCS 57.8 ± 21.5) than our cohort at a mean follow-up of 57.9 ± 43.1 months [37]. In the same stance, patients with unilateral transtibial amputation reported higher SF-36 scores (PCS 44.5 ± 7.8, MCS 52.5 ± 7.7) with a follow up of minimum one year, which highlights the persistent impact of FRI on the quality of life [38].

The low score of EQ-5D VAS rating of 62.1 reflects that even after recovery from FRI of the foot, patients rate their general well-being as significantly lower than the norm (72.9). But also in comparison to patients with FRI of the long bones (65.7), the subjective valuation is clearly worse [1]. Also, postoperative EQ-5D VAS ratings were higher (72.0 ± 16.2 vs. 62.1 ± 18.6) already six months after surgery in patients undergoing ankle arthrodesis for end-stage arthritis [39]. Intriguingly, a study accessing the subjective state of health reported higher values in EQ-5D and Manchester Oxford Foot Questionnaire following ambulatory foot surgery [40]. This confirms that after foot surgery without infection, the quality of life is significantly higher. Furthermore, it was shown that a normal quality of life after 76 months (median follow up time) could be achieved with a regular healing process after operative (n = 13) and conservative (n = 13) treatment of a Lisfranc's dislocation injury [41].

We consider restrictions in the categories pain/discomfort (100 %) and mobility (81.3 %) as the main concerns negatively affecting QOL in our cohort. In contrast, a better outcome concerning these categories was reported by Maher et al. after elective, ambulant foot surgery. However, the main difference by comparison with our collective was that their patients mainly underwent single location, solitary procedures of the foot, such as hallux valgus, hallux rigidus, or toe surgery, and therefore the patients did not require surgery due to an fracture and later a staged surgical treatment due to FRI [40]. Albrigth et al. identified a wound length of more than 10 cm in the area of the lower leg, as well as bone loss and muscle loss according to the OTA open fracture classification as risk factors for a reduced quality of life one year postoperatively [42]. In this case, the injury to the lower limb results in physical limitations and thus leading to socioeconomic and financial burdens that therefore negatively impact QOL [43,44].

Similar results were seen in the ISR, with depression, but also anxiety, being described as the leading stressors. From these results, it must be concluded that even after successful treatment of an FRI of the foot, the dejection and anxiety does not only refer to restrictions of movement, but also to the effects in private and professional life resulting from the physical limitation.

The main limitation of this study is that due to the retrospective design no baseline quality of life scores for the included patients exist. Further, the findings are limited in generalizability as the sample size was relatively small but also heterogenic regarding the surgical procedures. To address this problem, patients with multiple fractures were excluded from the study. However, it has to be acknowledged that eight patients (32.0 %) received an arthrodesis of

the ankle joint, whereas an amputation was performed in two patients (8.0 %), which might have contributed to lower quality of life scores. A subgroup analysis based on the different treatment modalities lacked significant effect power due to the small group size.

5. Conclusion

In summary, this study is intended to draw attention to the fact that FRI have been insufficiently emphasized in trauma surgery up to now, which becomes obvious by the fact that there has been a lack of a consistent definition of the term FRI. Moreover, this study aims to highlight the tremendous impact of an FRI of the foot on the health related quality of life. Thus, well-founded data of the patient-reported impact of FRI improves clinician-patient communication concerning the outcome expectations. FRI of the foot represents a major burden for the patient and his immediate environment. Physical and mental well-being of affected patients are restricted albeit successful treatment in terms of infect eradication and bone union has been achieved within a mean follow-up of 3.0 years. A patient-centered treatment approach focusing on improvement of QOL during and after treatment is therefore warranted.

Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

Declarations of Competing Interest

none.

References

[1] Walter N, Rupp M, Hierl K, Pfeifer C, Kerschbaum M, Hinterberger T, et al. Long-term patient-related quality of life after fracture-related infections of the long bones. Bone Jt Res 2021;10(5):321–7. https://doi.org/10.1302/2046-3758.105.BJR-2020-0532

[2] Metsemakers WJ, Morgenstern M, McNally MA, Moriarty TF, McFadyen I, Scarborough M, et al. Fracture-related infection: a consensus on definition from an international expert group. Injury 2018;49(3):505–10. https://doi.org/10.1016/j.injury.2017.08.040

[3] Walter N, Rupp M, Lang S, Alt V. The epidemiology of fracture-related infections in Germany. Sci Rep 2021;11(1). https://doi.org/10.1038/s41598-021-90008-w

[4] Thakore RV, Greenberg SE, Shi H, Foxx AM, Francois EL, Prablek MA, et al. Surgical site infection in orthopedic trauma: a case-control study evaluating risk factors and cost. J Clin Orthop Trauma 2015;6(4):220–6. https://doi.org/10.1016/j.jcot.2015.04.004

[5] Maurer E, Wallmeier V, Reumann M, Ehnert S, Ihle C, Schreiner AJ, et al. Erhöhtes Alter, kardiovaskuläre Nebenerkrankungen, COPD und Diabetes mellitus bedingen eine Übersterblichkeit in der septischen Unfallchirurgie. Z Orthop Unf 2022. https://doi.org/10.1055/a-1659-4823

[6] Amin S, Achenbach SJ, Atkinson EJ, Khosla S, Melton LJ. Trends in fracture incidence: a population-based study over 20 years. J Bone Min Res 2014;29(3):581–9. https://doi.org/10.1002/jbmr.2072

[7] Rupp M, Walter N, Pfeifer C, Lang S, Kerschbaum M, Krutsch W, et al. The incidence of fractures among the adult population of germany-an analysis from 2009 through. Dtsch Arztebl Int 2021(Forthcom) 2019. https://doi.org/10.3238/arztebl.m2021.0238

[8] Richter M. Vorfußfrakturen. Unfallchirurg 2011;114(10):877–82. https://doi.org/10.1007/s00113-011-1982-1

[9] Luetters CM, Keegan THM, Sidney S, Quesenberry CP, Prill M, Sternfeld B, et al. Risk factors for foot fracture among individuals aged 45 years and older. Osteoporos Int 2004;15(12):957–63. https://doi.org/10.1007/s00198-004-1625-2

[10] Buddecke DE, Polk MA, Barp EA. Metatarsal fractures. Clin Podiatr Med Surg 2010;27(4):601–24. https://doi.org/10.1016/j.cpm.2010.07.001

[11] Spierings KE, Min M, Nooijen LE, Swords MP, Schepers T. Managing the open calcaneal fracture: a systematic review. Foot Ankle Surg 2019;25(6):707–13. https://doi.org/10.1016/j.fas.2018.10.005

[12] Trampuz A, Zimmerli W. Diagnosis and treatment of infections associated with fracture-fixation devices. Injury 2006;37(Suppl 2):S59–66. https://doi.org/10.1016/j.injury.2006.04.010

[13] Metsemakers W-J, Onsea J, Neutjens E, Steffens E, Schuermans A, McNally M, et al. Prevention of fracture-related infection: a multidisciplinary care package. Int Orthop 2017;41(12):2457–69. https://doi.org/10.1007/s00264-017-3607-y

[14] Ktistakis I, Giannoudi M, Giannoudis PV. Infection rates after open tibial fractures: are they decreasing? Injury 2014;45(7):1025–7. https://doi.org/10.1016/j.injury.2014.03.022

[15] Kortram K, Bezstarosti H, Metsemakers W-J, Raschke MJ, van Lieshout EMM, Verhofstad MHJ. Risk factors for infectious complications after open fractures; a systematic review and meta-analysis. Int Orthop 2017;41(10):1965–82. https://doi.org/10.1007/s00264-017-3556-5

[16] Sun Y, Wang H, Tang Y, Zhao H, Qin S, Xu L, et al. Incidence and risk factors for surgical site infection after open reduction and internal fixation of ankle fracture: a retrospective multicenter study. Med (Baltim) 2018;97(7):e9901https://doi.org/10.1097/MD.0000000000009901

[17] Korim MT, Payne R, Bhatia M. A case-control study of surgical site infection following operative fixation of fractures of the ankle in a large U.K. trauma unit. Bone Jt J 2014;96-B(5):636–40. https://doi.org/10.1302/0301-620X.96B5.33143

[18] Bezstarosti H, van Lieshout EMM, Voskamp LW, Kortram K, Obremskey W, McNally MA, et al. Insights into treatment and outcome of fracture-related infection: a systematic literature review. Arch Orthop Trauma Surg 2019;139(1):61–72. https://doi.org/10.1007/s00402-018-3048-0

[19] Cooke ME, Hussein AI, Lybrand KE, Wulff A, Simmons E, Choi JH, et al. Correlation between RUST assessments of fracture healing to structural and biomechanical properties. J Orthop Res 2018;36(3):945–53. https://doi.org/10.1002/jor.23710

[20] Rupp M, Popp D, Alt V. Prevention of infection in open fractures: where are the pendulums now? Injury 2020;51(Suppl 2):S57–63. https://doi.org/10.1016/j.injury.2019.10.074

[21] Bullinger M, Kirchberger I, Ware J. Der deutsche SF-36 Health Survey Übersetzung und psychometrische Testung eines krankheitsübergreifenden Instruments zur Erfassung der gesundheitsbezogenen Lebensqualität. J Public Health 1995;3(1):21–36. https://doi.org/10.1007/BF02959944

[22] Brooks R. EuroQol: the current state of play. Health Policy 1996;37(1):53–72. https://doi.org/10.1016/0168-8510(96)00822-6

[23] Tritt K, Heymann F, von, Zaudig M, Zacharias I, Söllner W, Loew T. Entwicklung des Fragebogens "ICD-10-Symptom-Rating" (ISR). Z Psychosom Med Psychother 2008;54(4):409–18. https://doi.org/10.13109/zptm.2008.54.4.409

[24] Devlin NJ, Brooks R. EQ-5D and the EuroQol group: past, present and future. Appl Health Econ Health Policy 2017;15(2):127–37. https://doi.org/10.1007/s40258-017-0310-5

[25] Claes C., Greiner, W., Uber, A., Graf von der Schulenburg, J.M. An interview-based comparison of the TTO and VAS values given to EuroQol states of health by the general German population. In: Greiner W., Graf v.d. Schulenburg, J.M., Piercy, J., editors. EuroQol Plenary Meeting, 1–2 October 1998. Discussion papers. Witte: Uni-Verlag; 1999, p. 13–39.

[26] EuroQol - a new facility for the measurement of health-related quality of life. Health Policy 1990;16(3):199–208. https://doi.org/10.1016/0168–8510(90)90421–9.

[27] Ellert U, Kurth B-M. Methodische Betrachtungen zu den Summenscores des SF-36 anhand der erwachsenen bundesdeutschen Bevölkerung. Bundesgesundheitsblatt Gesundh Gesundh 2004;47(11):1027–32. https://doi.org/10.1007/s00103-004-0933-1

[28] Szende A., Janssen B., Cabases J. (eds.). Self-Reported Population Health: An International Perspective based on EQ-5D. Dordrecht (NL); 2014.

[29] Brinker MR, Hanus BD, Sen M, O'Connor DP. The devastating effects of tibial nonunion on health-related quality of life. J Bone Jt Surg Am 2013;95(24):2170–6. https://doi.org/10.2106/JBJS.L.00803

[30] Walter N, Kerschbaum M, Pfeifer C, Popp D, Freigang V, Hinterberger T, et al. Long-term patient-related quality of life after successfully treated aseptic nonunions of the long bones. Injury 2021;52(7):1880–5. https://doi.org/10.1016/j.injury.2021.04.041

[31] Schottel PC, O'Connor DP, Brinker MR. Time trade-off as a measure of health-related quality of life: long bone nonunions have a devastating impact. J Bone Jt Surg Am 2015;97(17):1406–10. https://doi.org/10.2106/JBJS.N.01090

[32] Zayzan KR, Yusof NM, Sulong AF, Zakaria Z, Ab Rahman J. Functional outcome and quality of life following treatment for post-traumatic osteomyelitis of long bones. Singap Med J 2020. https://doi.org/10.11622/smedj.2020164

[33] Liener UC, Enninghorst N, Högel J, Kinzl L, Suger G. Lebensqualität nach operativer Osteitisbehandlung. Unfallchirurg 2003;106(6):456–60. https://doi.org/10.1007/s00113-002-0566-5

[34] Lerner RK, Esterhai JL, Polomano RC, Cheatle MD, Heppenstall RB. Quality of life assessment of patients with posttraumatic fracture nonunion, chronic refractory osteomyelitis, and lower-extremity amputation. Clin Orthop Relat Res 1993;295:28–36.

[35] Monteban P, van den Berg J, van Hees J, Nijs S, Hoekstra H. The outcome of proximal fifth metatarsal fractures: redefining treatment strategies. Eur J Trauma Emerg Surg 2018;44(5):727–34. https://doi.org/10.1007/s00068-017-0863-x

[36] Westphal T, Halm J-P, Piatek S, Schubert S, Winckler S. Lebensqualität nach Kalkaneusfrakturen. Eine Matched-pairs-Analyse mit bevölkerungsrepräsentativer Kontrollgruppe. Unfallchirurg 2003;106(4):313–8. https://doi.org/10.1007/s00113-002-0565-6

[37] Dalat F, Trouillet F, Fessy MH, Bourdin M, Besse J-L. Comparison of quality of life following total ankle arthroplasty and ankle arthrodesis: Retrospective study of 54 cases. Orthop Trauma Surg Res 2014;100(7):761–6. https://doi.org/10.1016/j.otsr.2014.07.018

[38] Sarroca N, Valero J, Deus J, Casanova J, Luesma MJ, Lahoz M. Quality of life, body image and self-esteem in patients with unilateral transtibial amputations. Sci Rep 2021;11(1):12559. https://doi.org/10.1038/s41598-021-91954-1

[39] Rajapakshe S, Sutherland JM, Wing K, Crump T, Liu G, Penner M, et al. Health and quality of life outcomes among patients undergoing surgery for end-stage ankle arthritis. Foot Ankle Int 2019;40(10):1129–39. https://doi.org/10.1177/1071100719856888

[40] Maher AJ, Kilmartin TE. An analysis of Euroqol EQ-5D and Manchester oxford foot questionnaire scores six months following podiatric surgery. J Foot Ankle Res 2012;5(1):17. https://doi.org/10.1186/1757-1146-5-17

[41] Schepers T, Kieboom BCT, Kieboom B, van Diggele P, Patka P, van Lieshout EMM. Pedobarographic analysis and quality of life after Lisfranc fracture dislocation. Foot Ankle Int 2010;31(10):857–64. https://doi.org/10.3113/FAI.2010.0857

[42] Albright PD, Ali SH, Jackson H, Haonga BT, Eliezer EN, Morshed S, et al. Delays to surgery and coronal malalignment are associated with reoperation after open tibia fractures in Tanzania. Clin Orthop Relat Res 2020;478(8):1825–35. https://doi.org/10.1097/CORR.0000000000001279

[43] Parker B, Petrou S, Masters JPM, Achana F, Costa ML. Economic outcomes associated with deep surgical site infection in patients with an open fracture of the lower limb. Bone Jt J 2018;100-B(11):1506–10. https://doi.org/10.1302/0301-620X.100B11.BJJ-2018-0308.R1

[44] Backes M, Schep NWL, Luitse JSK, Goslings JC, Schepers T. The effect of postoperative wound infections on functional outcome following intra-articular calcaneal fractures. Arch Orthop Trauma Surg 2015;135(8):1045–52. https://doi.org/10.1007/s00402-015-2219-5