Aus dem Centrum für Muskuloskeletale Chirurgie
der Medizinischen Fakultät Charité – Universitätsmedizin Berlin

DISSERTATION

Complex foot trauma: amputation versus reconstruction – Clinical evaluation and long-term quality of life

zur Erlangung des akademischen Grades
Doctor medicinae (Dr. med.)

vorgelegt der Medizinischen Fakultät
Charité – Universitätsmedizin Berlin

von

Nesrin Al Khaled

aus
Liverpool

Datum der Promotion: 04.03.2022

Table of Contents

List of Figures

List of Tables

List of Abbreviations

3rd CST: 3rd grade closed soft tissue injury

3^{rd} OST: 3^{rd} grade open soft tissue injury

ALT flap: Anterior lateral thigh flap

ATA & PTA: Anterior and posterior tibial artery

BLK: Below knee amputation

CFT: Contralateral foot trauma

Deglov: Degloving injury

DPA: Dorsalis pedis artery

EDL & EDB: Extensor digitorum longus and brevis

EHB: Extensor hallucis brevis

FFA: Forefoot amputation

Free ALT: Free anterior lateral thigh flap

Free LD: Free latissimus dorsi flap

FX: Fracture

LPA: Lateral plantar artery

ORIF: Open reduction and internal fixation

PTA: Posterior tibial artery

RSF: Reversed sural flap

SFA: Subtotal foot amputation

SPN: Superficial peroneus nerve

STA: Subtotal foot amputation

STSG: Split thickness skin graft

TN: Tibial nerve

Abstract:

Background: Complex foot injuries are debilitating injuries that could negatively impact the quality of life of affected patients. For a long time, amputation was the typical treatment for these injuries. Today, advancements in surgical techniques allow for foot salvage in the treatment of complex foot trauma. With this change, the question has arisen as to which of the two treatments is the best option for patients? The objective of this work was to compare quality of life and clinical parameters in patients with condition after amputation and patients with condition after reconstruction of the foot after complex foot trauma. Similarly, bacterial contamination of open wounds of complex foot trauma was also investigated.

Patients and Methods: In a cross-sectional study, 26 patients with surgical intervention after complex foot trauma between the years 2003 and 2014 were interviewed about foot and joint function and quality of life. The German versions of the *foot function index*, the *foot pain scale*, the *foot function scale*, the *foot and ankle visual analog scale*, the *foot and ankle disability index* (FADI), the *body image quality of life inventory* (BIQI), and the *foot and ankle patient satisfaction questionnaire SF 36* were used. Information on trauma, surgical interventions, complications, bacterial cultures of open wounds, and further clinical course was collected retrospectively from patient documentation. Patients after foot amputation were compared with patients after foot reconstruction in terms of foot injury characteristics, number of surgical interventions, complications encountered, length of hospital stay, and concomitant polytrauma. Lastly, the Zwipp score correlation of the aforementioned variables was calculated.

Results: Twenty-two patients (76.9%) underwent foot reconstruction, and four patients (15.3%) underwent foot amputation. No significant difference was found in the mentioned parameters between the two groups except for the Zwipp score ($p = 0.009$). The functional scores were worse than the pain scores. No significant difference in quality of life was found between amputation and reconstruction groups. More than half of the microbiological cultures from open wounds were negative.

Conclusion: Complex foot trauma is disabling injury. Neither treatment (foot reconstruction and amputation) proved to be a superior option for patients. Functional limitations were the main causes of poor quality of life. With the improvement of functional rehabilitation programs, a better outcome can be expected in the future.

Zusammenfassung:

Hintergrund: Komplexe Fußverletzungen sind schwächende Verletzungen, die die Lebensqualität der betroffenen Patienten negativ beeinflussen könnten. Die Amputation war für lange Zeit die typische Behandlung für diese Verletzungen. Die Weiterentwicklung der chirurgischen Techniken ermöglicht heute die Fußrettung bei der Behandlung des komplexen Fußtraumas. Mit dieser Veränderung hat sich die Frage gestellt, welche von den beiden Behandlungen die beste Option für die Patienten ist. Zielsetzung der Arbeit war der Vergleich von Lebensqualität und klinischen Parametern bei Patienten mit Zustand nach Amputation und Patienten mit Zustand nach Rekonstruktion des Fußes nach komplexem Fußtrauma. Ebenso wurde auch die bakterielle Kontamination von offenen Wunden des komplexen Fußtraumas untersucht.

Patienten und Methoden: In einer Querschnittsstudie wurden 26 Patienten mit chirurgischer Intervention nach komplexem Fußtrauma zwischen den Jahren 2003 und 2014 zu Fuß- und Gelenkfunktion und zur Lebensqualität befragt. Anwendung fanden die deutschen Versionen des Fuß-Funktionsindex (FFI-D), der foot pain scale, der foot function scale, die visuelle Analogskala zu Fuß und Sprunggelenk, der Foot and ankle disability index (FADI), das Body image quality of life inventory (BIQI) und der foot and ankle patient satisfaction questionnaire SF 36. Informationen zu Trauma, chirurgischer Intervention, Komplikationen, Bakterienkulturen von offenen Wunden und weiterem klinischen Verlauf wurden retrospektiv aus Patientendokumentation erhoben. Patienten nach Fußamputation wurden mit Patienten nach Fußrekonstruktion verglichen in Bezug auf die Eigenschaften der Fußverletzungen, die Anzahl der chirurgischen Eingriffe, aufgetretene Komplikationen, die Dauer des Krankenhausaufenthaltes und die begleitenden Polytrauma. Zuletzt wurde die Zwipp-Score-Korrelation der genannten Variablen berechnet.

Ergebnisse: 22 Patienten (76,9%) erhielten eine Fußrekonstruktion, vier Patienten (15,3%) erhielten eine Fußamputation. Bei den genannten Parametern wurde kein signifikanter Unterschied zwischen den beiden Gruppen festgestellt mit Ausnahme des Zwipp-Score ($p = 0,009$). Die Funktionswerte waren schlechter als die Schmerzwerte. Es wurde kein signifikanter Unterschied in der Lebensqualität zwischen Amputations- und Rekonstruktionsgruppe festgestellt. Mehr als die Hälfte der mikrobiologischen Kulturen aus offener Wunde waren negativ.

Fazit: Komplexe Fußtraumata sind schwerwiegende Verletzungen. Keine der beiden Behandlungen (Fußrekonstruktion und Amputation) erwies sich als überlegene Option für die Patienten. Funktionelle Einschränkungen waren die Hauptursachen für eine geringe Lebensqualität. Mit der Verbesserung der funktionellen Rehabilitationsprogramme kann zukünftig ein besseres Ergebnis erwartet werden.

1. Introduction

1.1 Overview

“Man’s foot is all his own. It is unlike any other foot. It is the most distinctly human part of his whole anatomical makeup. It is a human specialization and, whether he be proud of it or not, it is his hallmark and so long as Man has been Man and so long as he remains Man, it is by his feet that he will be known from all other members´ of the animal kingdom”. - Frederick Wood Jones, 18th century British anatomist (1)

Man’s foot is the ultimate characteristic of humankind, it supports his unique upright position, and his various activities (walking, running, dancing, sport exercises etc.). The fact that, the foot as a result of its location at the end of the lower extremity, makes it very vulnerable to trauma. Actually, its injuries are seen on daily basis in emergency rooms (2).

Complex foot trauma is the result of a high energy insult, which causes injuries in several components of the foot. This can be an isolated injury, or a part of multiple trauma. According to Zwipp, complex foot trauma occurs in 52% of occurrences of multiple trauma, making the foot one of the most adversely affected organs in multiple trauma cases (3).

1.2 Etiology and classification of foot trauma

Foot trauma is categorized according to injury severity to “simple foot trauma,” where few components have been injured, and “complex foot trauma,” for more complex cases.

Zwipp created a scoring system to clarify what defines a complex foot trauma. He divided the foot into five anatomical planes. Lisfranc, Chopart, calcaneus, talus, and Pilon. Each dislocated or fractured plane adds one point to the score. Points are also added for soft tissue injuries as according to the Tscherne classification of soft tissue injuries. Each foot trauma with a final score of five points or more is considered a complex foot injury. Degloving and partial foot amputations score four points each (3).

The Tscherne classification of soft tissue injuries was issued by Harald Tscherne and Hans-Jörg Oestern in 1982 (4). It describes soft tissue injuries that combine both types of fractures - closed fractures and open fractures - regarding trauma energy. Each type

of injury is classified as one of four grades according to its severity and contamination. Any accompanying vascular injuries were considered a fourth injury degree (4). A complete description of Tscherne classification is found in the appendix.

Any high energy force can cause complex trauma to the foot. Motor vehicle accidents are the most common etiologies (5) (6). Vehicle accidents have reached high rates worldwide, and unfortunately airbags in cars do not protect feet from injuries (2).

Rising escalations around the world leave war victims with endangered limbs, and less efficient medical help. The absence of safety measures in industrial facilities, especially in developing countries, is also associated with a high amount of work-related foot injuries.

Foot trauma mostly affects the active young population. Naohiro Shibuya, using data from the American National Trauma Data Bank data set between 2007 and 2011, reported 43.87 +/- 19.25 years as the mean age of foot trauma injuries (7). This age group is considered the most productive group in the society. Such injuries within this group can cause economic, social, and of course emotional impact on the traumatized patient as well as his/her family and community.

According to Mackenzie and Castillo et al, the cost of two years of hospitalization as a result of isolated lower limb threatening injury ranged from $81,316 to $91,106, irrespective of whether the limb was amputated or reconstructed. Life time health care costs were $509,275 for an amputated limb, and $163,282 for a reconstructed limb (8). These alarming figures only consider direct health care costs. If these figures were to consider the financial loss due to patients' inability to work, the cost would be even greater.

The emotional and social impact of complex foot trauma should not be ignored either. Patients with complex foot trauma registered lower scores in the majority of pain, function, and satisfaction measures compared to patients with angina pectoralis or heart failure (9). In cases of multiple trauma, patients with complex foot trauma achieved lower emotional, social, and psychological scores compared with those without foot trauma (10). Unfortunately, foot injury occurrences are underestimated in most busy emergency rooms. In other words, they may be overlooked, especially in multiple trauma patients, and missed injuries could occur in 10% of patients with multiple injuries (11), in spite of the secondary and tertiary clinical evaluation. Because of these high, likely under-

reported complex foot trauma occurrences, many studies are concerned with the prevention and management of these injuries.

1.3 The bacterial load at admission

Complex foot traumas are usually accompanied by third degree soft tissue injuries. Contaminated open wounds are more vulnerable to infection. The susceptibility of large open wounds to infection is related to the amount of contamination, the accompanying vascular injury and tissue necrosis.

Wounds are classified into five categories regarding their vulnerability to infections. These are: surgical wounds, lacerations, abrasions, contusions, and large open wounds (12).

In this study, the bacterial contamination at the primary admission was assessed to determine the dominant organism in these wounds.

1.4 Surgical treatment

Foot amputation has since ancient times been the only known treatment of high energy foot trauma. Amputation was described in Hippocrates' writings as a treatment for extremity ischemic gangrene. Amputation principles were later defined by Ambroise Pare, and continued to be used by Pierre Joseph Desault, then Oliver. (13). Despite ancient attempts at foot salvage as part of a human instinct to preserve the unity of the body, the concept of foot reconstruction was not considered practical before both the development of wound management techniques in the First World War, and the innovation of antibiotics in the Second World War. The major obstacle facing surgeons at that time was vascular injuries. The advent of arterial repair techniques caused a dramatic decrease in amputation rates during the Korean conflict. 1960 was the start of the microsurgery era. These techniques could, with the help of the microscope, be performed on small vessels, thus marking a turning point in the history of lower extremity reconstruction. The ability to restore limb perfusion, and later the transfer of variable tissue components or replantation of the amputated limb itself made the salvage of many high energy lower extremity trauma possible. (14).

Meanwhile, the developments in bone fixation techniques and soft tissue reconstruction made foot salvage achievable in all reconstruction levels (bones, vessels, nerves, and soft tissue).

1.5 The development of the concept of patient's quality of life

Patient quality of life is a new concept. It was conceived as healthcare workers noticed that the routine disease measures in place were not enough to estimate patients' health condition (15). The term "quality of life" appeared first in 1920, but it was not publicly utilized till 1960, and the comprehensive measures were not invented until early 1970 (16).

The World Health Organization defines quality of life as: "an individual's perception of their position in life in the context of the culture and value systems in which they live, and in relation to their goals, expectations, standards and concerns" (15).

The scope of quality of life has widened to contain many aspects of patient's complaints, regarding various diseases and traumas. In addition, new elements of quality of life have been quantified to measure the impact of disease on patients' function, social life, emotional life, etc. (17). Generic tools in the form of questionnaires were developed to measure patients' quality of life. These questionnaires focused either on specific diseases, or organs. They were translated to many languages to facilitate their use in different populations.

1.5.1 German version of foot function index

This index was designed by a group of rheumatologists to assess foot and ankle complaints (18). The original version of the foot function index consisted of 3 subscales: pain, disability, and limitation of function. Later, it was refined to contain more items concerning patients' quality of life (19). In 2008, this foot function index was approved for use for German speaking population (20).

1.5.2 Visual Analogue Scale foot and ankle (VAS)

The Visual Analogue Scale was first validated by Richter et al (21). It is based on the former visual analogue scale, with scores ranging from 0 (the best result) and 10 (the worst).

1.5.3 Foot and Ankle Disability Index (FADI)

The Foot and Ankle Disability Index was first described by Martin et al in 1999, and was proven to be a valid self-reporting measure (22), (23), (24), (25).

1.5.4 Body Image Quality of Life Inventory (BIQI)

The Body Image Quality of Life Inventory is a parametric tool, aimed at detecting the patient's attitude toward his or her body, as a result of the presented illness or trauma. It was established by Cash et al (26). BIQI is an accepted generic scale that measures patient's satisfaction. BIQI has also been validated in other languages like Spanish in 2011(27).

1.5.5 Foot and ankle patient satisfaction questionnaire SF 36

This is a relatively old questionnaire. Its purpose is to evaluate patient satisfaction with their current medical situation. It was first created in 1995 by the RAND corporation group as a part of their Medical Outcome Study, and aimed to measure patients' quality of life. It was translated to and validated in many languages, including German (28).

1.6 The purpose of the study

Complex foot trauma is a deeply consequential injury. It causes major disability for patients, consumes time and financial resources, and has a strong impact on families.

The current treatment options for these injuries fall into two main categories: amputation and reconstruction.

This study aims to determine whether the two groups differ in terms of the following: patients' age at trauma, Zwipp score, type of injury, whether they had multiple trauma,

number of performed operations, and the length of hospital residency. The correlation between Zwipp score and rate of amputation was also calculated. It aimed also to detected their quality of life after trauma.

The primary bacterial burden of open wounds was reviewed to determine the most dominant organism contaminating open wounds of complex foot trauma.

2. Patients and Methods

2.1 Patients

Patients were selected from SAP Charité registration computer data base in the orthopedic and trauma department in Charité Virchow University hospital (Center of Musculoskeletal Surgery). The research targeted all patients who had foot trauma in the years between 2003 and 2014.

All patients with foot trauma between 2003 and 2014 were retrieved from the database. Fractures on all foot planes (Calcaneus, talus, tarsal, metatarsal, and phalanx) were reviewed during the study period, in addition to the accompanying foot soft tissue injuries. Only patients with fractures on more than an anatomic foot plane with associated soft tissue injury were included in the study.

The selected patients were verified regarding the inclusion criteria.

The inclusion criteria were:

1- Age at trauma ≥ 18 years

2- A foot injury that occurred in the years between 2003 and 2014

3- A foot trauma that scored ≥ 5 points in the Zwipp score system.

There were 75 patients with multiple foot trauma (with more than one foot bone fracture) and soft tissue injury, but only 26 of them (34.6%) met the inclusion criteria. Meanwhile, fifty-seven patients (62.6%) did not score five points or more on the Zwipp score, and one patient (1.33%) aged under18 years at time of trauma. Thus, the study included 26 patients.

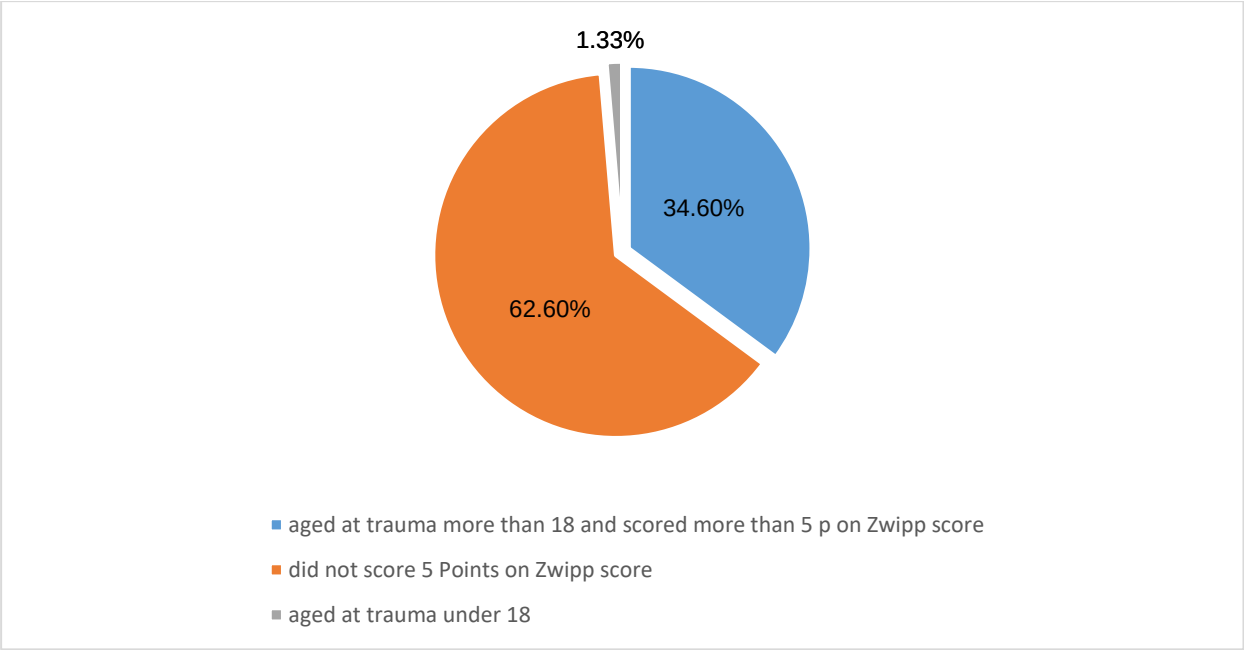

Figure 1: Patients with foot trauma. Distribution of patients eligible and not eligible for study inclusion.

2.2 Methods

2.2.1 Sample Data

Part of the study data was obtained from the selected patients' archives, including gender, age at trauma, isolated foot trauma vs. foot trauma as a part of multiple trauma, foot injuries, the number and type of surgical interventions, complications, the length of hospital stay, and bacterial contamination at admission.

The results of bacterial contamination at admission were obtained from the registered culture results of the wound bed at first surgical intervention directly after admission. Patients with complex foot trauma as a part of polytrauma were also considered.

Foot injuries in particular were categorized according to:

1- Level of injury according to Zwipp classification of foot injuries (3)

2- Open or closed injuries according to Gustilo open fracture classification (29).

3- Amputation or degloving injuries including partial amputations

4- Degree of soft tissue injury according to Tscherne soft tissue injuries classification (4)

5- Muscles, nerves, vessels, metatarsals, and phalanges injuries

The recorded treatments were classified according to conventional foot reconstruction methods in cases of foot trauma regarding osteosynthesis, and vascular and neural reconstructions ending with the definitive soft tissue coverage. Soft tissue reconstructions were also ordered according to the reconstructive ladder, or in specific cases reconstruction elevator. The reconstructive procedures included healing by secondary intention, primary closure, vacuum assisted closure, skin grafts, and local, regional, and free tissue transfer.

The last step was the complication register. The encountered complications were divided into three types:

- Infectious complications in cases of symptomatic invasion and multiplication of the severed foot with pathological microorganisms.
- Complications regarding the limb perfusion where limb blood perfusion was threatened as a result of raised intra-compartmental pressure (compartment syndrome) or ischemia due to vessel occlusion.
- Complications relating to the soft tissue coverage, such as flap or graft necrosis, and severe healing disorder.

2.2.2 Clinical scores

The quality-of-life data were collected using clinical scores. Five self-reported questionnaires were sent by post to the selected patients. Twelve out of 26 patients returned the answered questionnaires. Compliance rate was 46.1%.

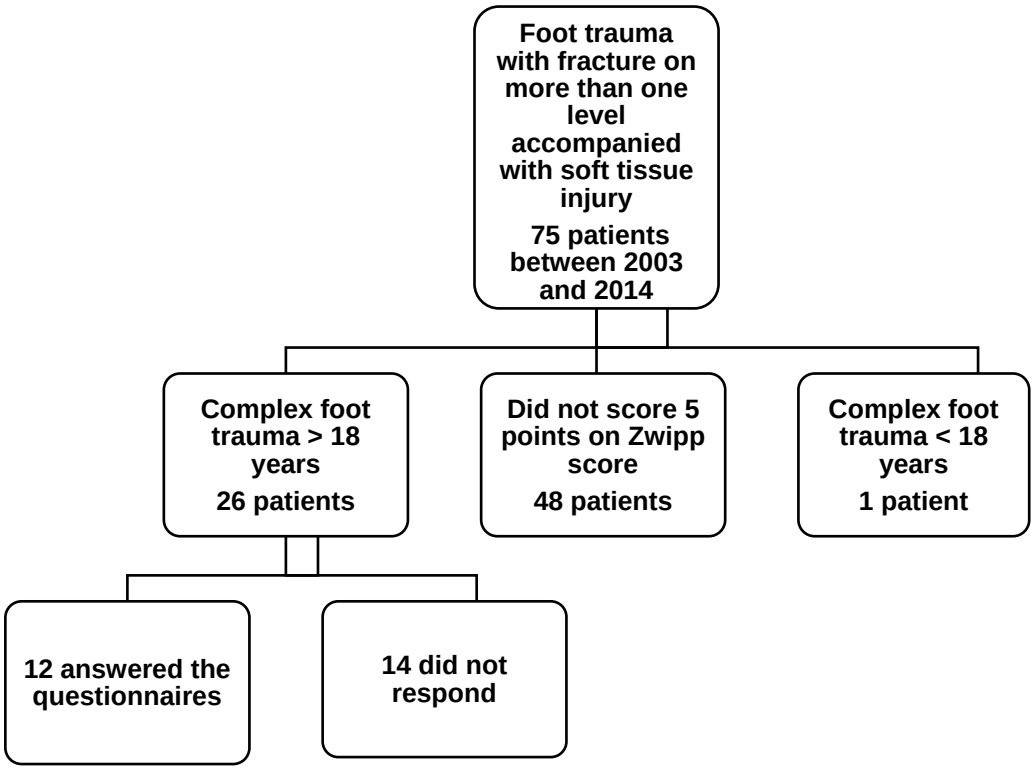

Figure 2: Patients' compliance of self-reporting questionnaires.

The questionnaires:

German version of foot function index: This index was adapted and has been considered valid for German speaking patients with foot complaints since 2008 (20). The questionnaire consists of two subscales, one dealing with pain scoring, the other with function scoring.

Foot pain scale: The foot pain scale consists of eight questions, measuring patient's pain in different situations: the worst cases, at night, in the morning, during the day, at the end of the day, walking with shoes, walking bare foot, and standing with shoes. Every question indicates a rating scale from 0 to 9, plus an additional choice to indicate not applicable (NA), if the question does not represent a location relevant to the patient's injury.

Foot function scale: A ten-question scale measured patients' difficulties performing various activities. Walking at home, walking for 1 km or more, walking on an even floor, walking on an uneven floor, walking up the stairs, walking down the stairs, standing on tiptoe, getting up from a chair, rapid walking or running, free time activity (sport) and

wearing special shoes (high heel shoes, sandals, etc.). Every question indicates a rating scale from 0 to 9, plus an additional choice not applicable (NA), if the question does not represent an activity relevant to the patient's injury.

Each section was calculated separately. The points from the marked questions were summed up, then divided by the maximum score achievable by all marked items, and then multiplied by 100 to get a percentage. Non-answered items were marked as NA (not applicable). The greater the score, the greater a patient's disability (20).

Visual analogue scale, foot and ankle: This scale consists of twenty questions covering a wide range of patient's pain and difficulty level as a result of foot trauma in different situations. The questions were categorized into three groups (pain: four questions, function: eleven questions, other complaints: five questions) (30). Each question is divided into intervals of 10 from best score (100) to the worst score (0). The maximum achievable score is 2000, thus the sum recorded by the patient was divided by 20 to obtain a percentage. Non-answered items were ignored; thus, the sum is divided by the number of answered questions.

Higher scores recorded by the patient indicate more function and less pain.

Foot and ankle disability index (FADI): The FADI consists of 26 items translated from English to German to suit our German speaking study group. It contains 22 activity related items and four pain related items (22, 24, 31). Each of the 26 items is rated on a five-point scale. The FADI has a total potential point value of 104 points, and scores were transformed into percentages. A 100% score would indicate no disability.

Body image quality of life inventory (BIQI): This BIQI is a nineteen-item instrument used to quantify the impact of body image on aspects of a patient's life (private, social, and sexual), in addition to his or her self-esteem (26). This was translated from English into German. Every item was scaled into seven bipolar points from -3 (very negative) to +3 (very positive). The final calculated figure presented a negative or positive value. It is interpreted as follows: the more negative the score, the more negative the body image.

Foot and ankle patient satisfaction questionnaire SF 36: The German version of foot and ankle patient satisfaction questionnaire SF 36 consists of 11 items. Two items concerned general health, two items role limitation due to physical health, one item role limitation due to emotional problems, two items for pain, two items for emotional well-being, and two items for social functioning. Every item was on a scale from 0 to 100. The final score

was a percentage from the total achievable points, where 100% represented the highest level of possible function.

2.2.3 Statistical analysis

Patients selected for this study were divided according to the final surgical treatment into two groups, amputation vs salvage. Groups' data have been obtained from patients' archives, including the type and severity of injury (which is reflected by Zwipp score), the number of proposed surgical interventions, the length of hospital stay, and complications. A Multivariable Pearson correlation coefficient test was used to detect the relationship between amputation and the above-mentioned records, as well as to overcome the small size of the compared groups. A Chi square test was utilized to compare primary amputation and reconstruction groups in terms of the collected archive data.

To detect whether there was any relationship between the Zwipp score and quality of life of patients with complex foot trauma, the correlation between Zwipp score and the results of self-reporting questionnaires regarding the quality of life of the studied group was calculated using a multivariable Pearson correlation coefficient test.

Statistical analyses were conducted at the $p < 0.05$ level of significance. In this study the data were presented and pointed out as tendencies. As a result of the small number of patients in each group, the significance was barely achieved. Therefore, the p-values were mentioned, but results are discussed even if the P value did not reach $p < 0.05$.

The results of bacterial contamination at admission have calculated as percentages. The outcome of the clinical scores has been calculated as already described in the former section.

All statistical tests were performed with SPSS software for windows.

3. Results

3.1 Group demography

Patients were between ages 18 and 72 years at time of trauma, and average age was 38.2±13.6 years. Three were female patients (11.5%), and 23 male patients. Mean age at trauma among the females was 48± 24.5 years (min. 23; max. 72). Mean age at trauma among the males was 37 ± 11.8 (min. 18; max. 55).

One of the three female patients had foot reconstruction (3.8% of total group), whereas two had primary foot amputation (7.6% of total group). Nineteen male patients had salvaged feet (73% of total group), two male patients had secondary amputation (7.6% of total group) and two male patients had primary foot amputation (7.6% of total group) (Table 1).

Table 1: Patients' demographics

	Females n = 3 (11.5%)	Males n = 23 (88.4%)
Primary amputation	2 (7.6%)	2 (7.6%)
Reconstruction	1 (3.8%)	19 (73.1%)
Secondary amputation	-	2 (7.6%)

3.2 Multiple trauma versus mono trauma

Complex foot trauma is a result of a high energy insult directly affecting the foot. Patients received their injuries in different circumstances. Seven of them had multiple trauma (26.9%), whereas 19 had isolated foot trauma (monotrauma) (73.1%). Regarding those with multiple trauma, two had primary amputation (7.6%) whereas five limbs were salvaged (13%). Looking at the rate of multiple trauma in reconstruction and amputation groups, two amputation patients (7.6%), and five reconstruction patients (22.7%) respectively suffered from polytrauma with no significant difference in multi trauma-rates between the amputated and reconstructed groups ($p = 0.26$) according to the Chi square test.

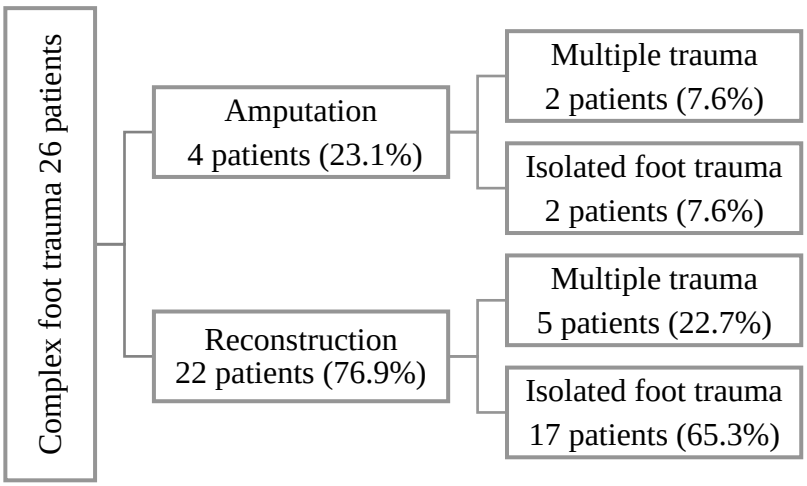

Figure 3: Type of trauma in study participants.

3.3 Patient groups

The patients were divided into two subgroups regarding their final treatment: primary amputation, or reconstruction. The characteristics of every subgroup have been studied separately.

Of the 26 patients who were diagnosed with complex foot trauma, four patients had primary foot amputation (15.3%), and 22 patients had foot salvage (76.9%). Two of the reconstructed patients (7.6%) had a secondary amputation as a complication. The overall amputation rate was 23%.

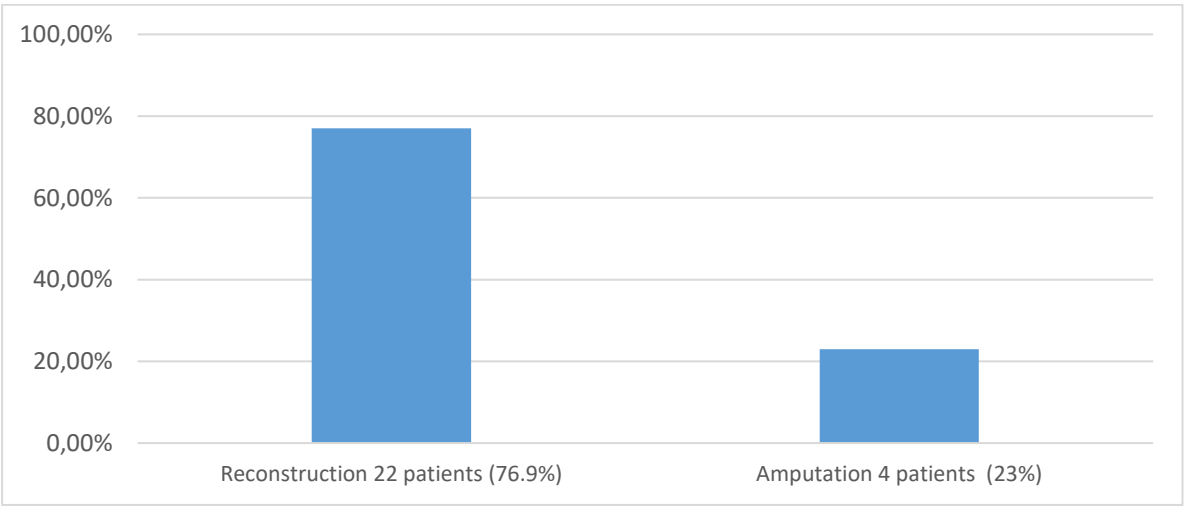

Figure 4: Distribution of study participants with amputation vs. reconstruction after foot trauma.

3.3.1 Primary amputation group

There were four patients aged between 25 and 72 years old at trauma, where mean age was 48.2 ± 19.2 years. Each patient in this group scored eight on the Zwipp score, 8 ± 0.

Multiple trauma: Two of the four patients (50%) had multiple trauma.

Injury: Table 3 presents the injuries in this group according to their Zwipp classification.

Table 2: Description of foot injuries of primary amputation group (3rd OST: 3rd grade open soft tissue injury, DPA: Dorsalis pedis artery, PTA: posterior tibial artery, FFA: Forefoot amputation, STA: Subtotal foot amputation)

Patient	Age (years)	Lisfranc injury	Chopart injury	Calca-neus injury	Talus injury	Pilon injury	Soft tissue injury	Other injuries	Zwipp score
1	72					X	3 OST	DPA and PTA. STA	8
2	47	X					3rdOST	FFA	8
3	25	X					3rdOST	FFA	8
4	49					X	3rdOST	FFA	8

As seen in the table, the injuries were on two anatomic levels: Lisfranc (50%) and Pilon (50%). All patients in this group had open soft tissue injuries, in addition to either a partial or forefoot amputation. Only one patient had serious vascular injury.

Treatment: Two patients (50%) received Chopart amputation, one patient (25%) received forefoot amputation, and one patient (25%) received below-knee amputation. They underwent surgical interventions on several occasions to close their injuries, including thorough cleansing, lavation, debridement, and some plastic surgery procedures. The mean number of operations was 5.5 ± 4.5 (min. 2, max. 12). Consequently, they had to stay stationary under hospital care for a considerable time; average hospital residency was 55 ± 26 days (min. 16, max. 69) (table 2).

Plastic surgery intervention: Two cases (50%) needed plastic surgical interventions: a mesh graft, and a free anterior lateral thigh flap. These interventions were used to cover the amputation stump and not to lengthen it.

Complications: Only one patient had a complication (Stump cellulitis), which corresponds with 25%.

Table 3: Treatment description of patients in the primary amputation group (ALT flap: anterior lateral thigh flap)

Patient	Age (years)	OP no.	Hospitali-zation	Multiple trauma	Type of amputation	Microsurgical& plastic surgical interventions	Compli-cations
1	72	2	69 days	Yes	below knee		
2	47	3	16 days		Chopart	Mesh graft	Stump cellulitis
3	25	12	67 days	Yes	forefoot		
4	49	5	68 days		Chopart	Mesh graft & free ALT flap	

3.3.2 Reconstruction group

The complex foot trauma was reconstructed in 22 patients (76.9%). These patients had various types of complex foot trauma. They were between 18 and 55 years old at time of trauma, average age was 36.45 ± 12 years. This group had relatively low Zwipp scores compared to the amputation group, ranging from five to nine. The mean Zwipp score was 6 ± 1.5 (table 5).

Multiple trauma: Five patients (22.7%) of the 22 patients had multiple trauma (table 4), and four patients had bilateral foot trauma (18.18%).

Injury: Table 4 delivers a full report of patients' injuries in this group. As a brief outline: eleven patients (50%) had either a Chopart or Lisfranc injury, ten patients (45.45%) had calcaneal injuries, nine patients (40.9%) had talus injuries, and only five patients (22.7%) had Pilon fractures. These fractures did not present alone, but along with other foot fractures as a part of complex foot trauma. Regarding soft tissue injuries: Twenty-one patients (96.5%) had open 3rd grade soft tissue injuries, and one patient (4.5%) had a 3rd grade closed soft tissue injury. Four patients (18,18%) had arterial injuries. Another two

patients (9%) had degloving injuries, three patients (13.6%) had partial foot amputation, and five patients (22.7%) had forefoot fractures.

It is worth mentioning that the two patients (patient no. 21 and patient no. 22) (table 4) who received secondary amputation had higher Zwipp scores (seven and eight respectively), and suffered from more severe arterial and bone injuries in comparison with other reconstructed patients. Patient no. 21 had complex foot trauma with serious vascular injury (dorsalis pedis artery and lateral plantar artery). Patient no. 22 had complex foot trauma on multiple levels according to the Zwipp description.

Treatment: Treatment began at the moment of admission with a thorough cleansing, lavation, debridement, fracture reduction and fixation, with three patients (13.6%), whose amputated feet were replanted as the first surgical procedure. All patients underwent an open reduction and internal fixation to fix their fractures, and three of them received both a closed reduction and internal fixation. An explanation of surgical treatment is found in table 6.

All members of this group went through several surgical interventions to close their injuries. Mean operation number was 7.45 ± 5.11 (min. 1, max. 21). Subsequently, the average hospital residency was 54.8 ± 42.1 days (min. 10, max. 206) (table 4). Table 5 illustrates the types and numbers of operations performed during hospitalization, not including outpatient visits (such as visits to remove the fixing materials).

Plastic surgery interventions: Sixteen patients (72.7%) required mesh graft to reconstruct their foot defects. Eight patients (31.8%) needed flaps. Of those, three had reversed sural flaps, one local flap, and three free flaps. Thus, six patients total required microsurgical interventions--three needed free flaps to reconstruct their soft tissue defect, and three received foot replantation at admission.

Complications: Seven patients out of our 22 patients suffered from complications during their treatment course, complication rate 31.8% (table 4). Four patients had infectious complications: two patients suffered from osteomyelitis, one patient had a wound infection, and one patient got cellulitis in addition to subsequent wound dehiscence. The fifth complicated case was flap necrosis and compartment syndrome. As mentioned earlier, two patients had secondary amputation: patient no. 21 (table 5) after an attempt at forefoot replantation which terminated with secondary Lisfranc amputation, and patient

no. 22 (table 5) who received a secondary forefoot amputation after several unsuccessful salvage efforts.

Table 4: Description of foot injuries of reconstruction group (3rd OST: 3rd grade open soft tissue injury, 3rd CST: 3rd grade closed soft tissue injury, CFT: Contralateral foot trauma did not meet the criteria of complex foot trauma, EHB: Extensor hallucis brevis, DPA: Dorsalis pedis artery, SPN: Superficial peroneus nerve, EDL & EDB: Extensor digitorum longus and brevis, SFA: Subtotal foot amputation, ATA, PTA: Anterior and posterior tibial artery, TN: Tibial nerve, BLK: Below knee amputation, Deglov: Degloving injury, FX: Fracture, FFA: Forefoot amputation, LPA: lateral plantar artery)

Patient	Age [years]	Lisfranc injury	Chopart injury	Calca-neus injury	Talus injury	Pilon injury	Soft tissue injury	Other injuries	Zwipp score
1	41		X	X			3rd OST		5
2	36			X	X		3rd OST	Cartilage injury CFT right	5
3	47		X		X	X	3rd OST		6
4	23			X	X		3rd OST	CFT left	5
5	35		X	X	X	X	3rd OST	CFT left	7
6	29			X		X	3rd OST	CFT left	5
7	28	X	X	X			3rd OST		6
8	52				X	X	3rd OST		5
9	52	X	X				3rd OST	EHB	5
10	55	X	X				3rd OST	DPA, SPN, EDB, EDL	5
11	27	X	X				3rd OST	FX Metatarsal and phalanges	5
12	33	X	X				3rd CST	Multiple contusions	5
13	53			X	X		3rd OST	SFA.	9
14	44			X	X		3rd OST	SFA. ATA, PTA, TN	9
15	30	X	X	X			3rd OST	TN	6
16	31		X		X		3rd OST	ATA, DPA	5
17	23			X			3rd OST	FX of I-VI Metatarsals, Deglov2	8
18	50	X	X				3rd OST	SFA, FX of all phalanges	9
19	23	X					3rd OST	Amputation of 5th toe, Deglov, VI degree contralateral FX tibial (BKA)	5
20	18	X					3rd OST	FX of 5th MTP	5
21	22	X	X		X	X	3rd OST	Luxation of MTP 5	7
22	50	X					3rd OST	DPA, LPA, SPN, EDL & EDB, FFA	8

Table 5: Description of treatment of patients of reconstruction group (ORIF: open reduction and internal fixation. STSG: split thickness skin graft, RSF: reversed sural flap, free ALT: free anterior lateral thigh flap. Free LD: free latissimus dorsi flap)

Patients	Age [years]	OP no.	Hospitalization [days]	Multiple trauma	Treatment	Complications
1	41	21	206	Multiple trauma	ORIF STSG RSF	Compartment syndrome of the foot Sural flap necrosis
2	36	2	60		ORIF Closed reduction	-
3	47	2	53		ORIF, STSG Local rotation flap	-
4	23	16	109	Multiple trauma	ORIF STSG, RSF	-
5	35	9	62	Multiple trauma	ORIF STSG	-
6	29	13	74		ORIF, STSG Closed reduction	Calcaneus osteomyelitis
7	28	6	43	Multiple trauma	ORIF, STSG, RSF	-
8	52	5	38		ORIF, STSG	-
9	52	7	51		ORIF STSG, Free ALT	-
10	55	5	21		ORIF, STSG	-
11	27	4	17		ORIF, STSG	-
12	33	6	53		ORIF Closed reduction	-
13	53	3	39		Replantation ORIF, STSG	-
14	44	5	60		Replantation ORIF STSG, Free LD	Wound infection
15	30	4	38		ORIF, STSG	-
16	31	5	14		ORIF	Talus osteomyelitis
17	23	7	39		ORIF STSG, Free ALT	Dry necrosis of 1st and 2nd toes Cellulitis, lymphangitis
18	50	10	56	Multiple trauma	ORIF	-
19	23	10	53		ORIF, STSG	-
20	18	1	10		ORIF	-

Table 5 cont.

Patients	Age [years]	OP no.	Hospitalization [days]	Multiple trauma	Treatment	Complications
21	22	9	58		ORIF STSG, fillet flap	Secondary below knee amputation
22	50	16	40		Foot replantation, ORIF, STSG	Secondary Lisfranc amputation

3.4 Primary amputation vs. reconstruction

As seen in the last two sections, patients in the two groups had dissimilar injuries and required different surgical interventions. They recorded diverse values in age, Zwipp score, hospital residency, the number of operations, surgical interventions and complications. They were compared among the above variables using Chi square test at $p < 0.05$.

Table 7 shows the mean values of age, multiple trauma rate, Zwipp score, operation number, and hospitalization in the two groups. The primary amputee patients were older than those in the other group. Mean age at trauma in the primary amputation group was 48.2 ± 19.2 years, whereas it was 36.45 ± 12 years in the reconstruction group, no significant difference was found between the two groups ($p = 0.32$). Multiple trauma rates differed between salvage and amputation groups; 22.7% of reconstructed patients, and 50% of primary amputee patients had multiple trauma, no significant difference was found ($p = 0.258$).

The amputation group had a significantly higher mean Zwipp score than the reconstruction group (8 ± 0 in primary amputation, 6 ± 1.5 in reconstruction group; $p = 0.009$). Interestingly, high Zwipp scores were also recorded in the two patients who had secondary amputations (7 and 8 points).

Concerning the number of operations, reconstructed patients went through more surgical interventions than the other group (5.5 ± 4.5 for primary and 7.45 ± 5.11 for reconstruction), however no significant difference was detected in operation number between the two groups ($p = 0.3911$).

Looking at the length of hospitalization, there was a non-significant difference between the two groups, (40.5 ± 0.7 days primary amputation vs 54.8 ± 42.1 days reconstruction; p = 0.3022).

At last, reconstructed patients suffered from more complications. Complication rate in the reconstruction group was 32% vs 25% in the primary amputation group (p = 0.7).

Table 6: Amputation vs reconstruction: Group characteristics

	Primary amputation	Reconstruction	p-value
Patients number	4	22	-
Age at trauma	48.2 ± 19.2 years	36.45 ± 12 years	0.3192
Multiple trauma	2 (50%)	5 (22.7%)	0.26
Zwipp score	8 ± 0	6 ± 1.5	**0.009**
Operation number	5.5 ± 4.5	7.45 ± 5.11	0.3911
Hospitalization	40.5 ± 0.7 days	54.8 ± 42.1 days	0.3022
complications	1 (25%)	7 (32%)	0.07

Foot injuries:

The table below shows a comparison between the two groups looking at the components of complex foot injury.

It is clearly observable that all patients had 3rd grade soft tissue injury. The reconstructed patients had various types of fractures on all Zwipp planes. The two patients who ended with secondary amputation had either severe vascular-neural injuries, or complex fractures on several Zwipp planes. In comparison, primary amputees' injuries were either Pilon or Lisfranc planes, and all of them had partial amputation. As a consequence, the amputation group has a significantly higher mean Zwipp score (p = 0.009) compared to the reconstruction group.

Table 7: Amputation vs reconstruction: Foot injuries

	Primary amputation	Reconstruction	p-value
Pilon	50%	22.7%	0.2667
Talus	0%	40.9%	-
Calcaneus	0%	45.45%	-
Chopart	0%	50%	-
Lisfranc	50%	50%	1
Partial amputation	100%	13.6%	-
Degloving	0%	9%	-
3rd degree soft tissue injury	100%	96.5%	-
Vascular injury	25%	18,18%	0.7
Nerve injury	0%	9%	-

Surgical treatments

All types of reconstructive interventions were used to treat the injuries in the studied groups. The reconstructed patients, of course, required more complex surgical interventions. All of them needed open reduction and internal fixation, vs 25% in amputees. Serial debridement was done on all of the salvaged patients, while only half of the primary amputees required these interventions. In addition, 73% and 36% of salvaged patients respectively had skin grafts and flaps (Figure 5). As mentioned earlier, no significant difference was detected between the groups in general operation number ($p = 0.3911$).

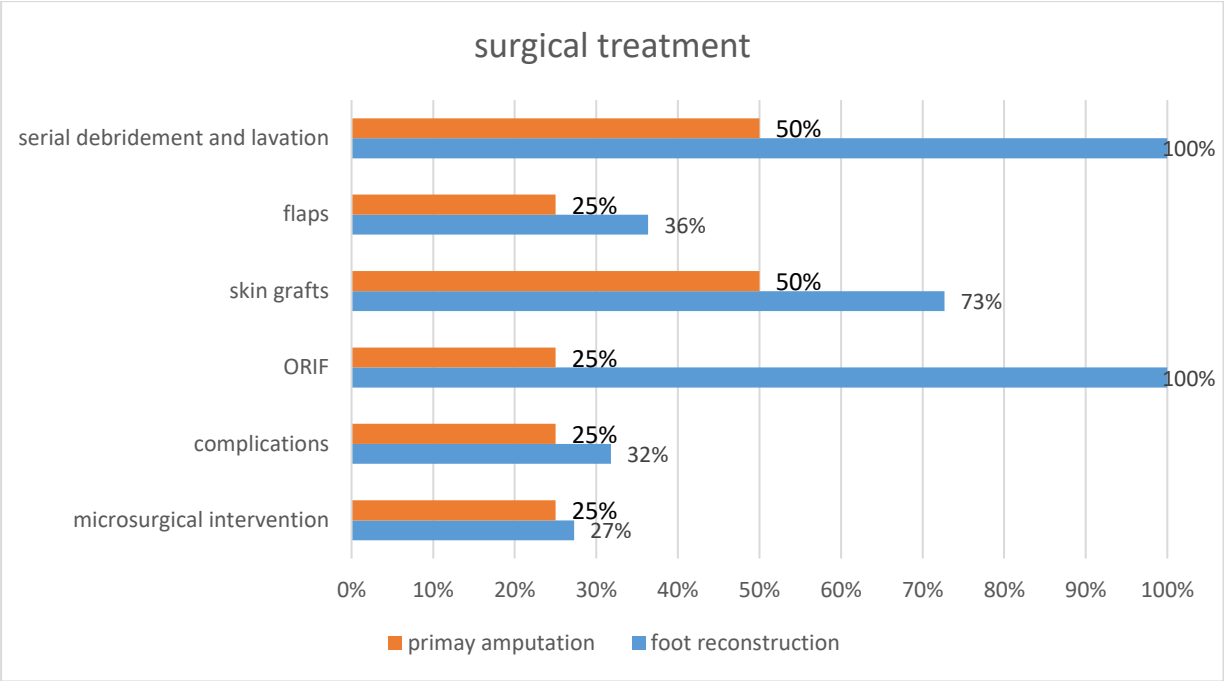

Figure 5: Amputation vs reconstruction: surgical treatment.

3.5 Bacterial load at the admission

The bacterial culture data from all open wounds in the studied group were collected from the patients' archive. The purpose of this was to determine which type of bacterial burden accompanies open wounds of complex foot trauma. Culture biopsies were harvested directly from the wound bed at admission. Twenty-six patients had complex foot trauma. Of these, 25 patients had a 3rd grade open wound foot injury, and one presented with 3rd grade closed soft tissue injury. Thus, 25 culture specimens were expected, but only 22 culture results were found in the computer database.

Two thirds of the studied specimens (63.6%) came out with a sterile culture, as primary cultures revealed no bacterial growth. The most cultured organisms were gram-negative bacteria dominated by pseudomonas (19.26%) Gram-positive species were detected in two patients (7.6%), and one patient had fungus (3.84%).

Table 8: Bacterial culture results of open wounds of complex foot trauma

Culture results	No of patients
No growth	14
Pseudomonas	3
Fungus	1
Staphylococcus hemolytic + Staphylococcus epidermis	1
Staphylococcus epidermis + Brevibacterium	1
Pseudomonas+ Pantoea agglomerans	1
Acinetobacter calcoaceticus	1

3.6 Clinical scores

Twelve out of 26 patients diagnosed with complex foot trauma returned the questionnaires. The compliance rate was 46.1%. Most of them had foot reconstruction (11 of 12: 91.6%). Ten of them (83%) were treated with foot reconstruction, one patient had primary foot amputation (8.3%), and one patient had secondary amputation. Compliance rate among salvaged patients was much higher than amputee patients (50% salvaged vs 25% amputee).

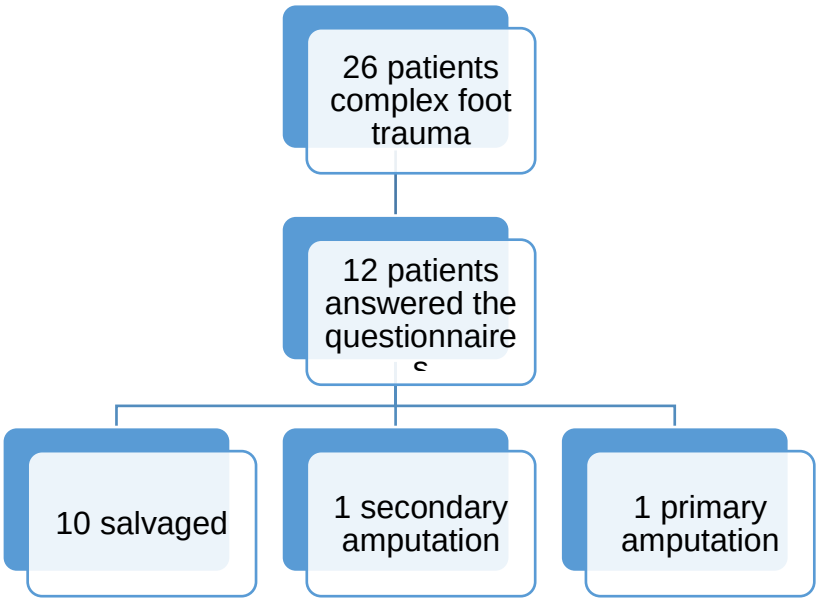

Figure 6: Compliance rate to self-reporting questionnaires.

The returned questionnaires revealed the following results:

Foot and ankle patient satisfaction questionnaire SF 36: Here the results were relatively moderate. Only nine patients answered this questionnaire, making the compliance with this questionnaire lower than the others. The worst SF 36 values were scored in SF 36 physical functioning (min 0%, max 80%, mean value 31.1% ± 29.9%), and SF 36 role limitation due physical health: (min 0% to max 100%, mean value 22.2% ± 38.4%). The mean values of the other roles were fairly close to the medium.

Table 9: SF36 values of patients with amputation vs patients with foot reconstruction

	Mean scores of salvage patients	Scores of amputee patient	p value
SF36 Physical functioning	35%	0%	-
SF36 Role limitation due to physical health	25%	0%	-
SF36 Role limitation due to emotional problems	70,8%	0%	-
SF36 Energy-fatigue	54,3%	40%	0.799
SF36 Emotional wellbeing	66,5%	36%	0.5742
SF36 Social functioning	67,3%	37,5%	0.5811
SF36 Pain	45,58%	22,5%	0.6786
SF36 General health	45,6%	45%	0.9915

Body image quality of life inventory BIQI: The lowest score was -33, and the highest was +17, and scores were overwhelmingly negative, with a mean BIQI score -6.9 ± 14. Notably, the amputation patients' records were near the mean, with the primary amputation patient at -8 and the secondary amputation patient at -6, while their mean value was -7 ± 1.4. The mean BIQI of reconstruction patients was -6.9 ± 15, p = 0.9929.

Visual analogue scale VAS: Candidates' mean values ranged from 10.8% to 83.5%. Mean VAS total was 38.3% ± 19.5%. The worst scores were found in finding suitable shoes (mean 22.5% ± 30.4%), in walking (mean 25.8% ± 23.5%), and regarding ankle rigidity (mean 26.6% ± 23%). Eight patients (66%) claimed that they did not return to work or cannot work anymore. One patient had severe work difficulties. Only three patients (25%) returned to work after follow-up times of three, five, and ten years respectively.

The mean VAS score of salvage patients was 37.3% ± 20.7%. The mean value of the two amputation patients was not far from the mean value of reconstructed patients at 43.5%

(primary amputation at 55.5%, and secondary amputation at 31.6%). There was no significant difference between the two groups in this scale p = 0.8748.

Foot function index FFI: FFI pain: the patients had fairly acceptable scores, ranging from 6.7% to 62.5%, and mean FFI pain was 34.89% ± 15.3%. Remarkably, half of the reconstructed patients documented that they cannot walk barefoot because of the pain.

FFI function: here the scores were obviously more negative. They ranged from 10% to 78.8%, and the mean FFI function was 50.3% ± 20.5%. Nine patients (75%) claimed that they cannot do sports, with three of them having difficulties in climbing stairs, and four unable to walk on even ground.

Looking at salvaged vs amputee patients, reconstructed patients had slightly higher mean values in both sections, but they were still statistically non-significant. FFI pain in the salvage group was 35.77% ± 16.4%, compared to FFI pain in the amputation group which was 30.5% (23.6% primary amputation and 37.4% secondary amputation), p = 0.8913. FFI function in salvage patients was 50.89% ± 22.7% vs 47.85% in amputation patients (47.7% primary amputation and 48% secondary amputation), p = 0.9401.

Foot and ankle disability index FADI: Patient's scores stretched from 25% to 78.8%. Mean FADI was 50.9% ± 15.4%. Interestingly, eight patients could not stand on tiptoe.

Amputation patients' scores were near the mean value of salvage patients' scores, which was 50.9% ± 15%. The secondary amputation patient's score was 65.3%, and the primary amputation patient's score was 37.5%, resulting in their mean value of 51.4%. P = 0.99.

Zwipp score and quality of life of patients with complex foot trauma: To detect if there was any relationship between the Zwipp score and quality of life of patients with complex foot trauma, the correlation between Zwipp score and the results of self-reporting questionnaires regarding the quality of life of the studied group was calculated. The results revealed a non-significant, weak correlation between the Zwipp score and each foot function index function (FFI function), as well as foot and ankle patient satisfaction questionnaire SF 36 in terms of limitations due physical health, and limitations due to emotional problems, energy-fatigue, emotional wellbeing, and social functioning (Table 11 and table 12). This non-significant weak correlation could not ascertain the relationship between Zwipp score and quality of life of patients with complex foot trauma.

Table 10: The correlation between Zwipp score and the results of BIQI, FADI, FFI pain, FFI function and VAS questionnaires

Correlation of Zwipp score with	BIQI	FADI	FFI pain	FFI function	VAS
r value	-0.256	- 0.2	-0.013	0.094	-0.054
p value	0.422	0.534	0.968	0.771	0.867

Only a week non-significant correlation was found between Zwipp score and FFI function.

Table 1: The correlation between Zwipp score and the results of foot and ankle patient satisfaction questionnaire SF 36 scores

Correlation of Zwipp score with	r value	p value
SF36 Physical functioning	-0.403	0.282
SF36 Role limitation due physical health	0.054	0.890
SF36 Role limitation due to emotional problems	0.057	0.883
SF36 Energy-fatigue	0.271	0.481
SF36 Emotional wellbeing	0.086	0.826
SF36 Social functioning	0.381	0.311
SF36 Pain	-0.020	0.960
SF36 General health	-0.161	0.679

A weak non-significant correlation was found between Zwipp score and SF36 in roles of limitation due physical health, limitation due to emotional problems, energy-fatigue, emotional wellbeing, and social functioning.

4. Discussion

This study is a cross-sectional study with additional retrospective data collection. It intended to compare options for the surgical treatment of complex foot trauma: primary amputation vs reconstruction. Treatments were compared in terms of hospitalization, number of operations, and complications. The factors that affect decision making of treatment of complex foot trauma (age, type of injury, Zwipp score) were also discussed. This study also aimed to investigate the quality of life of patients with complex foot trauma.

The results of bacterial culture of open wounds of complex foot trauma were also collected retrospectively. The dominant organism in these wounds at the time of trauma was registered.

4.1 Patients and Methods

Only adults from the population of patients with complex foot trauma were included. Most existing literature in this subject also considers only adult patients. Typically, adults are more expected to be involved in aggressive activities endangering their feet than children. Children are also less capable of expressing their feelings, and it is challenging to use quality of life questionnaires with them. However, children are still vulnerable to foot trauma. This leaves a serious gap in literature regarding this age of group (32).

Since 1997, the Zwipp score for complex foot trauma has been the golden standard, and the only classification used to define complex foot traumas (3). It quantifies damage in the five anatomical planes of the foot, foot soft tissue injuries, and foot subtotal amputations along with degloving injuries. It depends indirectly on Tscherne classification to express soft tissue traumatic injuries. Nonetheless, it does not consider vascular or neural injuries, which limits the accuracy and efficiency of this classification.

The aim of the quality-of-life questionnaires was to detect the quality of life of patients with complex foot trauma after treatment. Quality of life is a subjective concept that is not directly measurable (33). Furthermore, it is a multi-conceptual issue, including emotional, physical, functional, and social aspects (34). Therefore, several questionnaires regarding foot and ankle quality of life were used, in order to convey a full and clear impression of patients' quality of life.

The Foot and Ankle Disability Score (FADI) targeted the functional restrictions at work, and in daily activities. The German version of the Foot Function Index (FFI) had two domains, pain and general functional limitations. The Body Image Quality of Life Inventory (BIQI) examined the impact of foot injury on body image. Foot and Ankle Patient Satisfaction Questionnaire (SF 36) covered multiple topics, mainly the psychological impact of functional restrictions after foot trauma. The Visual Analogue Scale (VAS) focused on details of functional restriction after foot and ankle trauma. These questionnaires have proven to be reliable, internationally accepted tools to measure the quality of life of patients with foot injuries.

4.2 Results

4.2.1 General results

This study targeted patients with civil injuries, where there would have been safety measures in place to protect workers. Therefore, a high rate of complex foot traumas was not expected. All simple foot traumas were excluded from the study. Out of a total of 75 patients who had multiple foot trauma, only 26 patients older than 17 scored 5 P or more on the Zwipp scale.

Interestingly, the proportion of complex foot trauma was slightly higher in other centers, irrespective of age. Tietz in Regensburg University hospital found that complex foot trauma made up less than half of all types of foot trauma. In their study, out of 152 patients who had foot trauma only 74 had complex foot trauma (33). Grob et al reported a similar rate of complex hand trauma among total hand trauma occurrences. In their long-term study, 934 cases of complex hand trauma were noted out of 1952 cases of hand trauma (34).

Most victims in the group studied were relatively young: the mean age at trauma was 38.2 ± 13.6 years. It should be noted that Bennett et al selected a young group of patients, who had complex hindfoot trauma due to military injuries (35). Most victims in non-biased age reviews also belonged to the young population. Kinner et al. had a fairly young group of patients, with 43 years as the mean age at trauma (9). In a large review of 289,933 cases of foot and ankle trauma done by Daniel et al, the mean age at trauma was 42.59 years (7). In line with this pattern, many researchers have found a young average age at

trauma for the entire lower limb. When Russel studied 67 patients diagnosed with severe lower extremity trauma, the mean age was 31.9 years (ranging from 9 to 76 years) (36). In a large national review in China, it was found that lower extremity injuries mainly occur in the young population (37).

In this study, twenty-three patients (88.5%) were males, and only three (11.5%) were females. It should be noted that Demrilap and Tekin targeted male dominant groups of patients, land-mine workers and Turkish army soldiers respectively. Remarkably, even in larger, non-gender biased reviews males were more likely to have complex foot trauma (33). This feature was also remarkable among the victims of lower extremity trauma (38). Men are more commonly involved in violent and strenuous activities, which could make them more vulnerable to traumas. However, the gradual increased participation of females in such activities may expose them to more physical trauma including foot trauma.

Of 26 complex foot trauma cases in this study, seven patients (26.9%) had foot insults as a part of multiple trauma. Meanwhile, according to Zwipp in 1997, 52% of multiple trauma patients had complex foot trauma (3). This large difference might be attributed to the ongoing development of safety measure and means of protection over time. It has in recent decades become more possible to avoid multiple trauma, and to save extremities. The rate of hand injuries in multiple trauma patients has also reduced over time. According to Schaller in 1994, 20% of multiple trauma patients had hand injuries (39). Ten years later, only 6.7% of multiple trauma patients had forearm and hand injuries (40).

Amputation rate was 23%, further divided into primary amputation 15.3% and secondary amputation 7.6%. A similar amputation rate after complex foot trauma was reported by other authors. Tietz et al reported 24% (33), and Russel et al, 27% after severe lower limb trauma (36). Busse et al compared nine observational studies of complex lower extremity trauma (41), where amputation rate ranged from 18.36% primary amputation and 11% secondary amputation (42), to 45.45% primary amputation and 18% secondary amputation (43). Regarding the hand, amputation rate after severe hand trauma was 24.6% (34).

Only 12 patients out of the 26 patients (46.1%) responded to the sent questionnaires. The relatively low compliance rate could be attributed to the long follow up time (from 2 to 11 years). Ten patients changed their postal address (unbekannte Adresse). Three patients

refused to answer the questionnaires, and one patient was dead. This low compliance rate occurred in other studies as well. 35% (9).

4.2.2 Reconstruction vs amputation

Group characteristics and foot injuries

As clearly illustrated in the results section amputee patients were not older than salvaged patients; but they still had more severe injuries, and a higher Zwipp score.

Jupiter defined age as a risk factor for foot and ankle amputation after trauma (44). Conversely, to Russel et al, amputation patients are not significantly younger than reconstruction patients (the average age among amputees was 31.92 years vs 33.5 years among salvage patients) (36). This was confirmed by Demiralp et al as well (45). Similarly, in leg threatening injuries, no noteworthy difference was found in age between salvage and amputee patients (46). It should be noted that Demiralp et al and Tekin et al used small selected groups of male young patients in their studies (land-mine workers for Demiralp et al, and Turkish army soldiers for Tekin et al), which could explain the absence of age difference between amputation and reconstruction groups. However, even in large case-controlled studies, the results went in accordance with Tekin's and Demiralp's findings. After severe lower extremity trauma, 33% of reconstructed patients were over 40 whereas 27.3% of amputees were over 40, but the mean age of the two groups was similar at about 35 years (46).

In Busse et al's comparison review of nine studies regarding severe lower limb injuries, patients with more severe limb injuries were treated with limb amputation. They recommended proposing the treatment according to the severity of foot trauma (41). On the other hand, primary and secondary amputation correlated to soft tissue injury, and not to Zwipp scale (9). Nevertheless, Zwipp set the standard that the decision to amputate should depend on radiological and clinical examination of both soft and bone injuries and the situation of vessels and nerves, but did not define his score as an indicator for amputation (3).

There was no significant difference in the distribution of foot injuries between the two groups (regarding the anatomic foot planes). All patients in the two groups had 3rd degree soft tissue injuries, though they differed in the accompanying vascular, neural, and bone injuries. Amputation patients tended to have more vascular injuries. Moreover, one of the

two secondary amputee patients had serious vascular injury, and the other had multiple bone fractures with a high Zwipp score. Regarding the severity of injuries, higher Zwipp scores were associated with a higher possibility of foot amputation (p = 0.009).

Complex foot injuries treatment and complications

There was no significant difference in surgical interventions required. Yet, this study presented small groups, and the reconstruction group tended to require more surgeries (5.5 ± 4.5 operations for amputees vs. 7.45 ± 5.11 operations for reconstructed patients, p = 0.3911). Lange et al compared the number of operations needed for both salvaged and amputee patients after complex lower limb trauma. Salvaged patients required more surgical interventions (47). Moreover, a LEAP study recorded more necessary surgeries for salvaged patients than for primary amputees (38, 48). Georgiadis's report went in favor of their statement as well (43).

Despite the absence of a significant difference in lengths of hospital stay between the amputee and salvage groups, the amputees tended to have shorter hospital stays. The lengths of hospital stay between amputation and salvaged patients after severe lower limb trauma also differed among trauma centers (41). Nevertheless, Georgiadis, Hertel, and Hutchins reported shorter hospital residencies for amputation patients (41, 43, 49, 50). Reconstructed patients were more likely to be re-hospitalized (38, 48).

On the subject of complications, the overall complication rate after complex foot trauma was 30% (salvaged and amputee patients). These complications were mainly infections. The figure in this study was slightly less than the figure described in Kinner et al's review of (32%) (9). In this study, despite the absence of a significant difference between the two groups (p = 0.07), amputees were likely to have fewer complications than salvaged patients (25% among amputees vs 32% reconstructed). Complications were more prevalent among salvage patients than amputation patients even after complex lower extremity traumas (38). Furthermore, complex lower extremity trauma patients who underwent below-knee amputation were generally hospitalized for a routine follow up, as opposed to salvaged patients, who were admitted for complications (46). Meanwhile, in a LEAP study and other studies, after a complex lower extremity trauma, salvage patients were more often afflicted by osteomyelitis (38, 48). Georgiadis and Busse found an obviously higher complication rate among reconstruction patients (41, 43). Salvage patients also had more leg swelling (41, 51).

4.2.3 Bacterial load at the admission

Bacterial cultures of open leg complex trauma were dominantly sterile (63.6%). Only 23.1% of the cultured biopsies were positive. The most predominant cultured organisms were gram negative (pseudomonas) (19.26%). The rates of bacterial growth after a traumatic open wound differed between relevant clinical reviews. Then again, they revealed that more than half of open traumatic wounds showed no bacterial growth. In one of Murray's studies, 61 specimens from traumatic open war wounds were cultured and 49% of them were sterile. The dominantly cultured organisms were gram positive (93%) (52). Other reports investigated the cultures of 46 open wound fractures, and only 28.3% of these specimens showed bacterial growth (53). Additionally, of 70 pre-debridement cultures of open fractures, about half of them were positive (51.42%), and 66.66% of the cultured organisms were gram positive (54). As mentioned earlier, open wounds of complex foot trauma are to some extent, sterile wounds. Empiric antibiotic therapy might therefore be avoidable in visibly clean wounds. Thorough debridement and close observation of infection signs would still be necessary. However, the data from the literature still supports prophylaxis antibiotic therapy for all open fracture wounds (55-59).

4.2.4 The quality of life of patients with complex foot trauma

The results illustrated the causes of low quality of life for patients with complex foot trauma. This finding was also found in a Letizia et al publication (60). The causes of this low quality of life were mainly the functional restrictions, which the patients experienced during active foot movements in particular (60), and they were then followed by pain. Unfortunately, this deprived patients from participating in work life or doing sports and other recreation activities. Generally, surgery restores the patient's anatomy. Meanwhile, rehabilitation programs and physiotherapy are designed to restore limb or stump function. They prepare patients to reintegrate into social and work life. Müller et al ascertained that psychological impairment is a clear consequence of complex foot trauma. It should be followed up upon and addressed by rehabilitation (48). In other words, the psychological impairment in the results discussed reflects serious deficiencies in follow up systems and physiotherapy, as well as in psychological and work rehabilitation programs. Contrary to

Bennett et al', they connected the poor outcomes after complex hindfoot trauma to the features of the injuries (35).

Foot and ankle patient satisfaction questionnaire short form 36 (SF 36)

Patients' recorded scores were notably dissimilar. They generally ranged from poor to moderate. Compared to the general population, patients with foot injuries had more negative SF 36 scores (61). In this study, the patients were deeply affected by loss of function, more so than they were by the emotional impact of complex foot trauma. They reported their worst outcomes in SF 36 Role Limitations Due to Physical Health, followed by Physical Functioning. Meanwhile, their most positive reports were in SF 36 Emotional Wellbeing and SF 36 Social Functioning. SF 36 Emotional Wellbeing scores and SF 36 Social Functioning scores were more positive than SF 36 Physical Functioning and SF 36 Limitation Due to Physical Health scores among multiple trauma patients with foot injuries (62).

Body Image Quality of Life Inventory (BIQI)

There was a wide range found among BIQI score results. The lowest score was -33, and the highest was +17. This could be due to a difference in socioeconomic classes of the patients in this study, perhaps along with different accident circumstances. This range has also been detected in Demiralp's work (45). Even if foot injuries are covered by clothing or prosthetics, they still negatively affect patients' satisfaction with their bodies. Subsequently, patients' scores were overwhelmingly negative (45). Likewise, the mean BIQI score in this review was starkly negative -6.9 ± 14, irrespective of the proposed treatment (amputation or reconstruction).

Visual Analogue Scale Foot and Ankle (VAS)

Patients' scores were relatively low on the VAS, ranging from 10.8% to 83.5%. The mean VAS value was 38.3% ± 19.5%. Tietz et al's results were more optimistic (their mean VAS was 42.85%); but then again, they were in accordance with this study's results (33).

Unfortunately, only three patients (25%) returned to work. A better return to work rate was reported by other authors. For instance, in the LEAP study, the return-to-work rate ranged between 49% and 53% in 2 years following severe lower limb trauma (48). In a Kinner et al review, this percentage was 53% for both amputee and salvage patients (9). 30% of salvage patients and 63% of amputees returned to work in a Dagum et al publication (42). At last, Bosse observed that 53% of amputees and 49.4% of reconstructed patients

returned to work after complex lower extremity trauma (38). Though the mentioned reviews did not mention whether the patients had work rehabilitation programs, but it reflected the need of more work rehabilitation programs among the studied group.

VAS results were aligned with those of the SF 36. Function scores were worse than pain scores. Patients were affected by function loss more than pain, which prohibited engagement in their work. The explanation for this finding could be found in the answers of the other questionnaire items. Half of the studied participants described themselves as exhausted, and half of those could only wear orthotics shoes, or had difficulties in finding suitable shoes. On top of that, 50% of them suffered from ankle rigidity, which caused walking difficulties.

Foot and Ankle Disability score (FADI) and German version of the Foot Function Index (FFI)

Both questionnaires concerned foot related movements.

Patients had moderate FADI outcomes. The mean FADI score was 50.9% ± 15.4% (max 78.8% min 25%). Demiralp also found modest outcomes among foot reconstruction patients, with a mean FADI value of 64.3 ± 18.1 (45). Interestingly, eight patients could not stand on tiptoe, which could be due to foot joint rigidity or pain. This complaint would add an additive restriction to foot function after complex foot trauma.

Again, the results of FFI function were more negative than FFI pain scores. FFI scores showed that 75% of the patients were unable to do sports, and half of them could not walk with bare feet because of pain. Meanwhile, Kinner et al reported better scores, that only 41% of patients with complex foot trauma could do sports compared to the 77% who could do sports before trauma. On the other hand, Kinner et al also reported that 71% of patients were not able to do their recreation activities after trauma (9). This finding means that these relatively young patients were deprived from doing their sports or hobbies, and were more likely to be restricted indoors than they had been previously.

Quality of life of patients with complex foot trauma, amputation vs reconstruction

Though the relevant literature mentioned that, salvage patients are expected to have a lower quality of life (63,64), all utilized scales showed no significant difference in quality of life between reconstructed and amputee patients. Even treatment related factors that could affect the quality of life for patients with complex foot trauma, such as number of

surgical interventions, length of hospital stay, and rate of complications were not significantly different between the two groups.

In fact, all studied patients suffered from low quality of life irrespective of the proposed treatment. In the amputation group, the potential benefits of the absence of joint rigidity, chronic limb pain, and orthotics related complications were out weighed in the amputation group by the psychological influence of limb loss, prostheses related complications, and chronic phantom pain.

According to the LEAP study, there was no significant difference in quality of life and the functional outcome between reconstructed patients and amputated patients after foot or lower extremity complex trauma (38, 51, 65). Tekin found a better quality of life in general health, vitality, and pain scores among amputation patients (46). Meanwhile, Lange's results presented better functional outcomes with primary amputation (41, 47).

However, Demiralp and Dagum compared the SF 36 values between salvage and amputee patients, and the results did not favor one treatment's outcomes over the other (42, 45).

Pain reports from Dagum, Dahl, and Georgiadis showed no significant difference between amputation and reconstruction patients after foot or lower extremity complex foot trauma; (41-43, 51). Meanwhile Hertel's results were in favor of salvage patients (50).

At last, salvage patients were more satisfied with their bodies, with a mean BIQI of 5.7 ± 15.8, compared to -8.4 ± 19.8 in amputation patients (45). Salvage patients were also more content with the aesthetic outcome after treatment (66).

Zwipp score and quality of life of patients with complex foot trauma

No correlation was found between the Zwipp score and the quality-of-life scores of patients with complex foot trauma. However, though Zwipp score defined the severity of foot trauma (3); it did not correlate with the functional outcome or general wellbeing of patients with these injuries. Here, other factors could affect the quality of life of patients with complex foot trauma, like socioeconomic and educational class, rehabilitation programs, and psychological support programs (67). Kinner also found no relationship between Zwipp score and outcome of scores regarding quality of life, but rather, connected the long-term functional outcome with the severity of bone and joint injuries (9).

Even in cases of complex trauma of the whole extremity, no clear connection was recorded between the severity of trauma and the quality of life of the affected patients (38). Neither the severity of fracture and soft tissue injury, nor the presence of associated injuries of the ipsilateral and contralateral limb significantly affected the functional outcome of lower extremity complex trauma (38). Bosse et al also confirmed the effects of psychological and social factors on the quality of life of patients with complex lower extremity trauma (38). Furthermore, in O'Toole et al's study, patient satisfaction after treatment was determined by functional, pain, and depression outcome more than the severity of injury or treatment (68).

4.3 Limitation

The present study is a retrospective review, recruited a small cohort of patients, which limited the accuracy of statistical tests. Therefore, any insignificant difference could rather be described as a tendency.

The clear discrepancy of groups size (four amputation patients vs 22 salvage patients) was another limitation.

Only adults with complex foot trauma were included, so the results may not be representative of a younger age group. This added another limitation to this study.

The Zwipp score (3) did not include neural or vascular injuries as part of its scoring system, but considered soft tissue injuries indirectly depending on Tscherne classification (4). Such serious injuries deeply influence decision making in deciding treatment (amputation vs reconstruction) of complex foot trauma. It was not possible in this review to determine a protocol for treatment of complex foot trauma (amputation or reconstruction) according to Zwipp score (3). However, this score was significantly higher in the amputation group.

Though, all amputation patients had below knee amputation on different levels, The results of amputation group were discussed irrespective of the level of amputation, due to the limited group size. In addition to this, two patients had primary reconstruction and then secondary amputation. These patients were considered as salvage patients and not amputation patients.

A notable limitation was the low compliance rate among the group studied. Only 12 patients out of the 26 contacted patients (46.1%) responded to the sent questionnaires. As has already been discussed, the relatively low compliance rate could be explained by the long follow up time, and the retrospective nature of this study. Another difficulty was that in order to convey a wide spectrum of results regarding the quality of life of studied patients, five questionnaires were used, and some patients (3 patients) were unwilling to answer the long questionnaire SF 36. On top of this, the questionnaires had some overlapping questions, which could not be avoided and two of them (FADI and BIQI) had no valid German translation.

5. Conclusion

Unfortunately, complex foot trauma still represents a challenge to surgeons. It demands a multidisciplinary team and long-term rehabilitation. At the same time, it is incapacitating for patients, and is psychologically debilitating as well as having high associated financial costs.

To this day, neither amputation nor reconstruction has proven itself to result in a better functional outcome, which directly relates to them having worse psychological outcomes. On top of this, there is no scoring system that can predict the clinical outcome.

This study illustrated the direct relationship between functional and psychological rehabilitation and the outcome after a complex foot trauma. It shed the light on the importance of functional rehabilitation and Psychological supporting programs. Thus, reevaluation and improvement of rehabilitation and physiotherapy programs are needed to enhance quality of life for this group of patients.

This study encountered a limited cohort of adult patients. As a consequence, larger reviews are needed to detect the clinical outcome of complex foot trauma, including Children popultion. In addition to this, the next step should be to establish a new practical scoring system to evaluate the outcome.

6. References

1. Mowrey WS. Principles and Practice of Podiatry: Calif Med. 1969 Oct;111(4):341.
2. Schepers T, Rammelt S. Complex Foot Injury. Foot and Ankle Clinics. 2017;22:193-213.
3. Zwipp H, Dahlen C, Randt T, Gavlik J. Complex trauma of the foot. Der Orthopäde. 1997;26(12):1046-56.
4. Ibrahim DA, Swenson A, Sassoon A, Fernando ND. Classifications In Brief: The Tscherne Classification of Soft Tissue Injury. Clinical orthopaedics and related research. 2017;475(2):560-4.
5. Benirschke S, DiGiovanni C, Fowble VA, Greisberg J, Hansen Jr ST, Kadel NJ, Mills W, Pinney S, Roberts MM, Sands A. Volume 14 January 2004 Number.
6. SANGEORZAN BJ, HANSEN JR ST. Early and late posttraumatic foot reconstruction. Clinical orthopaedics and related research. 1989;243:86-91.
7. Shibuya N, Davis ML, Jupiter DC. Epidemiology of foot and ankle fractures in the United States: an analysis of the National Trauma Data Bank (2007 to 2011). The Journal of Foot and Ankle Surgery. 2014;53(5):606-8.
8. MacKenzie EJ, Castillo RC, Jones AS, Bosse MJ, Kellam JF, Pollak AN, Webb LX, Swiontkowski MF, Smith DG, Sanders RW. Health-care costs associated with amputation or reconstruction of a limb-threatening injury. The Journal of Bone & Joint Surgery. 2007;89(8):1685-92.
9. Kinner B, Tietz S, Müller F, Prantl L, Nerlich M, Roll C. Outcome after complex trauma of the foot. Journal of Trauma and Acute Care Surgery. 2011;70(1):159-68.
10. Turchin DC, Schemitsch EH, McKee MD, Waddell JP. Do foot injuries significantly affect the functional outcome of multiply injured patients? Journal of orthopaedic trauma. 1999;13(1):1-4.
11. Stiegelmar R, McKee MD, Waddell JP, Schemitsch EH. Outcome of foot injuries in multiply injured patients. Orthopedic Clinics of North America. 2001;32(1):193-204.
12. Leaper DJ. ABC of wound healing: Traumatic and surgical wounds. BMJ: British Medical Journal. 2006;332(7540):532.

13. Kasabian A, Karp N. Lower extremity reconstruction. Grabb and Smith's Plastic Surgery 6th ed Philadelphia: Wolters Kluwer Health/Lippincott Williams & Wilkins. 2007.

14. Mackenzie DJ, Seyfer AE. 158 Reconstructive Surgery: Lower Extremity Coverage. 2007.

15. Skevington SM, Lotfy M, O'Connell KA. The World Health Organization's WHOQOL-BREF quality of life assessment: psychometric properties and results of the international field trial. A report from the WHOQOL group. Quality of life research: an international journal of quality of life aspects of treatment, care and rehabilitation. 2004;13(2):299-310.

16. Wood-Dauphinee S. Assessing quality of life in clinical research: from where have we come and where are we going? Journal of clinical epidemiology. 1999;52(4):355-63.

17. The Development of the World Health Organization Quality of Life Assessment Instrument (the WHOQOL)1994; Berlin, Heidelberg: Springer Berlin Heidelberg.

18. Budiman-Mak E, Conrad KJ, Roach KE. The Foot Function Index: a measure of foot pain and disability. Journal of clinical epidemiology. 1991;44(6):561-70.

19. van der Zwaard B. Foot Function Index. Encyclopedia of Quality of Life and Well-Being Research: Springer; 2014. p. 2328-30.

20. Naal FD, Impellizzeri FM, Huber M, Rippstein PF. Cross-cultural adaptation and validation of the Foot Function Index for use in German-speaking patients with foot complaints. Foot & ankle international. 2008;29(12):1222-31.

21. Richter M, Zech S, Geerling J, Frink M, Knobloch K, Krettek C. A new foot and ankle outcome score: Questionnaire based, subjective, Visual-Analogue-Scale, validated and computerized. Foot and ankle surgery. 2006;12(4):191-9.

22. Hale SA, Hertel J. Reliability and sensitivity of the Foot and Ankle Disability Index in subjects with chronic ankle instability. Journal of athletic training. 2005;40(1):35.

23. Eechaute C, Vaes P, Van Aerschot L, Asman S, Duquet W. The clinimetric qualities of patient-assessed instruments for measuring chronic ankle instability: a systematic review. BMC Musculoskeletal Disorders. 2007;8(1):6.

24. Carcia CR, Martin RL, Drouin JM. Validity of the Foot and Ankle Ability Measure in athletes with chronic ankle instability. Journal of athletic training. 2008;43(2):179-83.

25. Martin RL, Irrgang JJ. A survey of self-reported outcome instruments for the foot and ankle. Journal of Orthopaedic & Sports Physical Therapy. 2007;37(2):72-84.

26. Cash TF, Fleming EC. The impact of body image experiences: development of the body image quality of life inventory. International Journal of Eating Disorders. 2002;31(4):455-60.

27. Lobera J, Rios B. Body image and quality of life in a Spanish population. Int J Gen Med. 2011;4:63-72.

28. Bullinger M, Kirchberger I, Ware J. Der deutsche SF-36 Health Survey Übersetzung und psychometrische Testung eines krankheitsübergreifenden Instruments zur Erfassung der gesundheitsbezogenen Lebensqualität. Zeitschrift für Gesundheitswissenschaften = Journal of public health. 1995;3(1):21.

29. Kim PH, Leopold SS. In brief: Gustilo-Anderson classification. [corrected]. Clinical orthopaedics and related research. 2012;470(11):3270-4.

30. Angthong C, Chernchujit B, Suntharapa T, Harnroongroj T. Visual analogue scale foot and ankle: validity and reliability of Thai version of the new outcome score in subjective form. Journal of the Medical Association of Thailand. 2011;94(8):952.

31. Eechaute C, Vaes P, Van Aerschot L, Asman S, Duquet W. The clinimetric qualities of patient-assessed instruments for measuring chronic ankle instability: a systematic review. BMC Musculoskeletal Disorders. 2007;8(1):1.

32. Lickstein LH, Bentz ML. Reconstruction of pediatric foot and ankle trauma. The Journal of craniofacial surgery. 2003;14(4):559-65.

33. Tietz S. Lebensqualität nach komplexer Fußverletzung: Regensburg, Universität Regensburg, Diss., 2013; 2013.

34. Grob M. Quality of life assessment after severe hand injury: Technische Universität München; 2007.

35. Bennett PM, Stevenson T, Sargeant ID, Mountain A, Penn-Barwell JG. Outcomes following limb salvage after combat hindfoot injury are inferior to delayed amputation at five years. Bone & Joint Research. 2018;7(2):131-8.

36. Russell WL, Sailors DM, Whittle TB, Fisher Jr DF, Burns RP. Limb salvage versus traumatic amputation. A decision based on a seven-part predictive index. Annals of surgery. 1991;213(5):473.

37. Lu S, Han P, Wen G, Wang C, Wang Y, Zhong W, Wang H, Chai Y. Establishing an Evaluation System and Limb-Salvage Protocol for Mangled Lower Extremities in China. JBJS. 2019;101(18):e94.

38. Bosse MJ, MacKenzie EJ, Kellam JF, Burgess AR, Webb LX, Swiontkowski MF, Sanders RW, Jones AL, McAndrew MP, Patterson BM. An analysis of outcomes of reconstruction or amputation after leg-threatening injuries. New England Journal of Medicine. 2002;347(24):1924-31.

39. Schaller P, Geldmacher J. [Hand injury in polytrauma. A retrospective study of 782 cases]. Handchirurgie, Mikrochirurgie, plastische Chirurgie: Organ der Deutschsprachigen Arbeitsgemeinschaft fur Handchirurgie: Organ der Deutschsprachigen Arbeitsgemeinschaft fur Mikrochirurgie der Peripheren Nerven und Gefasse: Organ der V. 1994;26(6):307-12.

40. Aldrian S, Nau T, Weninger P, Vécsei V. Hand injury in polytrauma. Wiener Medizinische Wochenschrift. 2005;155(9-10):227-32.

41. Busse JW, Jacobs CL, Swiontkowski MF, Bosse MJ, Bhandari M, Group E-BOTW. Complex limb salvage or early amputation for severe lower-limb injury: a meta-analysis of observational studies. Journal of orthopaedic trauma. 2007;21(1):70-6.

42. Dagum AB, Best AK, Schemitsch EH, Mahoney JL, Mahomed MN, Blight KR. Salvage after severe lower-extremity trauma: are the outcomes worth the means? Plastic and reconstructive surgery. 1999;103(4):1212-20.

43. Georgiadis G, Behrens F, Joyce M, Earle A, Simmons A. Open tibial fractures with severe soft-tissue loss. Limb salvage compared with below-the-knee amputation. J Bone Joint Surg Am. 1993;75(10):1431-41.

44. Jupiter DC, Shibuya N, Clawson LD, Davis ML. Incidence and risk factors for amputation in foot and ankle trauma. The Journal of Foot and Ankle Surgery. 2012;51(3):317-22.

45. Demiralp B, Ege T, Kose O, Yurttas Y, Basbozkurt M. Amputation versus functional reconstruction in the management of complex hind foot injuries caused by land-mine explosions: a long-term retrospective comparison. European Journal of Orthopaedic Surgery & Traumatology. 2014;24(4):621-6.

46. Tekin L, Safaz Ý, Göktepe AS, Yazýcýođlu K. Comparison of quality of life and functionality in patients with traumatic unilateral below knee amputation and salvage surgery. Prosthetics and orthotics international. 2009;33(1):17-24.

47. Lange RH, Bach AW, Hansen ST, Johansen KH. Open tibial fractures with associated vascular injuries: prognosis for limb salvage. J Trauma. 1985;25(3):203-8.

48. Müller CW, Krettek C, Decker S, Hankemeier S, Hawi N. [Limb salvage or amputation after severe trauma to the lower extremities : Evidence from the LEAP Study]. Der Unfallchirurg. 2016;119(5):400-7.

49. Hutchins P. The outcome of severe tibial injury. Injury. 1981;13(3):216-9.

50. Hertel R, Strebel N, Ganz R. Amputation versus reconstruction in traumatic defects of the leg: outcome and costs. Journal of orthopaedic trauma. 1996;10(4):223-9.

51. Dahl B, Andersson AP, Andersen M, Andersen GR, Ebskov LB, Reumert T. Functional and social long-term results after free tissue transfer to the lower extremity. Annals of plastic surgery. 1995;34(4):372-5.

52. Murray CK, Roop SA, Hospenthal DR, Dooley DP, Wenner K, Hammock J, Taufen l, Gourdine E. Bacteriology of War Wounds at the Time of Injury. Military Medicine. 2006;171(9):826-9.

53. Hasan O, Rahim Khan HA, Mustafa SF, Muhammad ZA, Ahmad T. Use of bacterial cultures in open wound fractures: A prospective cohort study. IJS Short Reports. 2018;3(1):52-7.

54. Agarwal Y, Batra B. The Journey Within. Journal of Orthopedics, Traumatology and Rehabilitation. 2015;8(1):1-5.

55. Saveli CC, Belknap RW, Morgan SJ, Price CS. The role of prophylactic antibiotics in open fractures in an era of community-acquired methicillin-resistant Staphylococcus aureus. Orthopedics. 2011;34(8):611-6; quiz 7.

56. Otchwemah R, Grams V, Tjardes T, Shafizadeh S, Bathis H, Maegele M, Messler S, Bouillon B, Probst, C. Bacterial contamination of open fractures - pathogens, antibiotic resistances and therapeutic regimes in four hospitals of the trauma network Cologne, Germany. Injury. 2015;46 Suppl 4:S104-8.

57. Elniel AR, Giannoudis PV. Open fractures of the lower extremity: Current management and clinical outcomes. EFORT Open Rev. 2018;3(5):316-25.

58. Cross WW, 3rd, Swiontkowski MF. Treatment principles in the management of open fractures. Indian journal of orthopaedics. 2008;42(4):377-86.

59. Hauser CJ, Adams CA, Jr., Eachempati SR. Surgical Infection Society guideline: prophylactic antibiotic use in open fractures: an evidence-based guideline. Surg Infect (Larchmt). 2006;7(4):379-405.

60. Letizia S, Mario M, Isabella P, Giulia F, Danya F, Michele R, Antonio G. Foot fractures and complex trauma of the foot: a case series. European journal of orthopaedic surgery & traumatology: orthopedie traumatologie. 2021.

61. Westphal T, Piatek S, Schubert S, Schuschke T, Winckler S. Lebensqualität nach Fußverletzungen. Zentralbl Chir. 2002;127(03):238-42.

62. Tran T, Thordarson D. Functional Outcome of Multiply Injured Patients with Associated Foot Injury. Foot & Ankle International. 2002;23(4):340-3.

63. Noblet, T., Lineham, B., Wiper, J. Amputation in Trauma—How to Achieve a Good Result from Lower Extremity Amputation Irrespective of the Level. Curr Trauma Rep. 2019,2 (5)**:** 69–78.

64. Doukas, William C, Hayda, Roman A, Frisch, H Michael, Andersen, COL Romney C, Mazurek, Michael T, Ficke, James R, Keeling, John J, Pasquina, Paul F, Wain, Harold J, Carlini, Anthony R, MacKenzie, Ellen J. The Military Extremity Trauma Amputation/Limb Salvage (METALS) Study. The Journal of Bone & Joint Surgery. 2013 Jan 16;95(2):138-145

65. MacKenzie EJ, Bosse MJ. Factors influencing outcome following limb-threatening lower limb trauma: lessons learned from the Lower Extremity Assessment Project (LEAP). J Am Acad Orthop Surg. 2006;14(10 Spec No.):S205-10.

66. Black CK, Ormiston LD, Fan KL, Kotha VS, Attinger C, Evans KK. Amputations versus Salvage: Reconciling the Differences. J reconstr Microsurg.32(EFirst).

67. Momoh AO, Chung KC. Measuring outcomes in lower limb surgery. Clinics in plastic surgery. 2013;40(2):323-9.

68. O'Toole RV, Castillo RC, Pollak AN, MacKenzie EJ, Bosse MJ. Determinants of patient satisfaction after severe lower-extremity injuries. J Bone Joint Surg Am. 2008;90(6):1206-11.

Eidesstattliche Versicherung

„Ich, Nesrin Al khaled, versichere an Eides statt durch meine eigenhändige Unterschrift, dass ich die vorgelegte Dissertation mit dem Thema: *Complex foot trauma: amputation versus reconstruction – Clinical evaluation and long-term quality of life* selbstständig und ohne nicht offengelegte Hilfe Dritter verfasst und keine anderen als die angegebenen Quellen und Hilfsmittel genutzt habe. Alle Stellen, die wörtlich oder dem Sinne nach auf Publikationen oder Vorträgen anderer Autoren/innen beruhen, sind als solche in korrekter Zitierung kenntlich gemacht. Die Abschnitte zu Methodik (insbesondere praktische Arbeiten, Laborbestimmungen, statistische Aufarbeitung) und Resultaten (insbesondere Abbildungen, Graphiken und Tabellen) werden von mir verantwortet.

Ich versichere ferner, dass ich die in Zusammenarbeit mit anderen Personen generierten Daten, Datenauswertungen und Schlussfolgerungen korrekt gekennzeichnet und meinen eigenen Beitrag sowie die Beiträge anderer Personen korrekt kenntlich gemacht habe. Texte oder Textteile, die gemeinsam mit anderen erstellt oder verwendet wurden, habe ich korrekt kenntlich gemacht.

Meine Anteile an etwaigen Publikationen zu dieser Dissertation entsprechen denen, die in der untenstehenden gemeinsamen Erklärung mit dem/der Erstbetreuer/in, angegeben sind. Für sämtliche im Rahmen der Dissertation entstandenen Publikationen wurden die Richtlinien des ICMJE (International Committee of Medical Journal Editors; www.icmje.og) zur Autorenschaft eingehalten. Ich erkläre ferner, dass ich mich zur Einhaltung der Satzung der Charité – Universitätsmedizin Berlin zur Sicherung Guter Wissenschaftlicher Praxis verpflichte.

Weiterhin versichere ich, dass ich diese Dissertation weder in gleicher noch in ähnlicher Form bereits an einer anderen Fakultät eingereicht habe.

Die Bedeutung dieser eidesstattlichen Versicherung und die strafrechtlichen Folgen einer unwahren eidesstattlichen Versicherung (§§156, 161 des Strafgesetzbuches) sind mir bekannt und bewusst.“

27.03.2021
Datum Unterschrift

Lebenslauf

Mein Lebenslauf wird aus datenschutzrechtlichen Gründen in der elektronischen Version meiner Arbeit nicht veröffentlicht

Acknowledgement

I would like to express my sincere thanks to the following people, without whom I would not have been able to complete my doctoral degree. Foremost, I am deeply indebted to my supervisor Prof. Dr. Björn Dirk Krapohl who gave me the opportunity to write this dissertation. I am grateful for his kindness, invaluable mentorship, tutelage and supervision throughout my doctoral degree. I am extremely thankful to my supervisor PD Dr. Sebastian Manegold for his corrections, unwavering guidance, collegial support and patience during the course of my doctoral degree. My gratitude extends to the team in Charité Virchow University hospital (Center of Musculoskeletal Surgery), especially to PD Dr. Serafim Tsitsilonis for his support in shaping my statistics. I am also grateful to Dr. Hani Harb for his advices.

I am also thankful to all patients who responded to my invitations, and took the time to complete my questionnaires.

Finally, I would like to offer my deep appreciations to my parents, my husband and my children. Without their unparalleled understanding and encouragement in the past few years, it would not be possible for me to complete my doctoral degree.

Nesrin Al Khaled Berlin, Germany, March 2021