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# Gait analysis and functional outcomes after twelve-week rehabilitation in patients with surgically treated ankle fractures

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ABSTRACT

Ankle fractures are the most common type of lower extremity fractures. The objective of our study was to analyse the changes of temporal and spatial gait parameters and functional outcomes in patients with bimalleolar fractures who followed surgery and rehabilitation compared to healthy controls. 49 patients with ankle fractures and 21 age-matched healthy volunteers were recruited. There were two assessments for the study group: T1 – once weight-bearing was allowed and T2 – twelve weeks after exercise-based rehabilitation programme. Each evaluation consisted in a functional questionnaire (Olerud-Molander Ankle Score-OMAS) and temporal and spatial gait parameters analysis. The gait parameters were analysed using a Zebris FDM platform. 30 patients completed the final assessment and their data were analysed. In T1 assessment there were significant differences in all temporal and spatial gait parameters between the patients group and controls. In T2 evaluation step time in affected ankle and non-affected ankle, swing time and stance time on affected ankle, stride time and cadence showed no significant differences in patients compared with controls. The within-group analysis showed significant differences in all temporal and spatial gait parameters except for single support time on non-affected ankle after rehabilitation. The OMAS improved significantly from T1 to T2 in all subscales except for squatting. Median value of OMAS improved from 60 (35–90) to 95 (55–100). Our study revealed significant improvements of all temporal and spatial gait parameters, as well as of the functional outcome in patients with surgically treated ankle fractures after twelve-week rehabilitation.



## 1. Introduction

Ankle fractures are the most common type of lower extremity fractures. Unstable bimalleolar and trimalleolar injuries are usually surgically treated [1,2]. Operative treatment includes open reduction and internal fixation, followed by immobilization and rehabilitation [3].

Temporal and spatial gait parameters analysis is widely used to characterize functional performance of different populations [4,5]. But only a small number of studies have focused on temporal and spatial parameters analysis in patients with ankle fractures. When compared to healthy controls, patients with ankle fracture who needed surgery and immobilization present altered gait patterns and clinical symptoms [6]. Wang et al. assessed patients 1 year after surgically treated ankle fractures. When compared to the non-injured side, single-support time on the injured side was shorter [7].

A combination of gait analysis and activities of daily living assessment offer information about functional limitations and rehabilitation of gait and mobility after an injury and surgical treatment [8].

A recent systematic review showed that after ankle surgery patients who performed active exercises returned earlier to daily activities and work [9].

According to our knowledge the analysis of temporal and spatial gait parameters before and after rehabilitation was not previously performed in patients with surgically treated ankle fractures. The exercise-based programme plays an important role in the management of patients with surgically treated ankle fractures. The evaluation of temporal and spatial parameters before and after rehabilitation is essential in individualising the

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physical exercise programme. Gait parameters analysis allows documenting the patients' progress after rehabilitation and gives the possibility to adapt the exercise programme in order to achieve full functional status. These aspects were not discussed in any previously published study.

The objective of our study was to analyse the changes of temporal and spatial gait parameters and functional outcomes in patients with bimalleolar fractures who followed surgery and rehabilitation compared to healthy controls.

Our primary hypothesis was that patients with surgically treated ankle fractures after twelve-week rehabilitation would have improved temporal and spatial gait parameters and functional parameters. These parameters should be similar to the healthy controls.

## 2. Methods

### 2.1. Subjects

Forty-nine patients with ankle fractures were selected from patients addressed to the Department of Rehabilitation, "Victor Babes" University of Medicine and Pharmacy Timisoara. Inclusion criteria were supra-syndesmotic bimalleolar fractures surgically treated with open reduction and internal fixation (according to AO/ASIF methods): ORIF plates and screws for medial malleolus, and screws and tension band for lateral malleolus as needed to achieve rigid fixation [10].

Exclusion criteria were: additional injury apart from the ankle fracture, other musculoskeletal disorders, and history of neurological diseases, vestibular or visual disturbances or any other pathology that would impair their motor performance or their ability to complete self-assessment questionnaires.

Seven patients met exclusion criteria: severe knee osteoarthritis (1), lumbar herniated disk (3), stroke (1), high myopia (1) and benign paroxysmal vertigo (1). Three patients refused to participate in the study. We have enrolled thirty-nine patients from which one was lost to follow up (moved abroad) and eight discontinued the rehabilitation programme. Thirty patients completed the final assessment and their data were analysed. There are no data missing from the training sessions. The subjects who dropped out did not differ significantly in clinical characteristics and gait parameters at baseline from the ones who completed the study (data not shown). The data of the subjects who dropped out were not analysed.

Twenty-one age-matched healthy volunteers were recruited as controls. They had no history of any musculoskeletal or neurological disorders. They were part of a larger database of volunteers from the Platform of Implantology, Intelligent Prosthetics and Biomechanical Rehabilitation from Timisoara Technical University, Mechanical Faculty, most of them employees.

Participation in the study was voluntary and written informed consent was obtained from all participants. The study was approved by the Ethics Committee of "Victor Babes" University of Medicine and Pharmacy, Timisoara, Romania and is in accordance with the Helsinki Declaration.

### 2.2. Assessment

Patients and controls characteristics were collected. The protocol of our study consisted in two assessments for the study group: the first one – once the weight-bearing was allowed (6–8 weeks after surgery – T1) and the second one – twelve weeks after exercise-based rehabilitation programme (T2). Each evaluation consisted in a questionnaire and temporal and spatial gait parameters analysis.

#### 2.2.1. Questionnaire

Patients were asked to complete the Olerud-Molander Ankle Score (OMAS). It is a self-administered questionnaire. The scale is a functional rating scale from 0 (totally impaired) to 100 (completely unimpaired) and is based on nine different items: pain, stiffness, swelling, stair climbing, running, jumping, squatting, supports and activities of daily living. OMAS has been frequently used to evaluate subjectively scored function after ankle fracture [7,11–13].

#### 2.2.2. Temporal and spatial gait parameters analysis

In our evaluation we used Zebris FDM platform, a device running on capacitive forces sensors, arranged in a $208 \times 56$ cm size matrix. The system from Timisoara Technical University, Mechanical Faculty is provided with WinFDM software [14–18]. The main gait parameters are shown in the evaluation report. These include the stride length, step length, step time and the percentages of different phases of gait cycle according to Rancho Los Amigos terminology (load response time, stance time, preswing time, swing period, single support time). Before data collection every patient walked on the platform in order to familiarize with the test procedures. Data were collected for five trials for each patient. The average of three good evaluations was considered for the results. A good evaluation was that in which a patient stepped with both feet at least three times on the platform and had no breaks in the gait cycle, with a self preferred speed.

The following temporal and spatial gait parameters were recorded: step time (s), stride time (s), step length (cm), stride length (cm), stance time (%), swing time (%), load response time (%), preswing time (%), single support time (%), cadence (step/min) and velocity (cm/s).

For the control group we took into consideration the dominant-leg. In adults, leg side dominance is considered to be given by the mobilizing functions of the lower limb, such as when kicking or juggling a ball [19,20].

### 2.3. Rehabilitation programme

The goals of the rehabilitation treatment were: restoring ankle mobility, muscle strength, balance and coordination, retraining walking and abilities like jumping, climbing and running. During the first two weeks patients were hospitalized in the Rehabilitation Department and followed a daily exercise-based programme for ankle mobility, circulation, walking and thera-band for muscle strength. During the next 6 weeks, the programme consisted in three sessions per week in the outpatient Rehabilitation Department. The patients performed progressively mobility and thera-band strength exercises, walking forward, backward, side-wards and stairs up and down. Jumping on the trampoline and wobble-board exercises began after 6 weeks of rehabilitation. During the last 4 weeks the outpatient rehabilitation programme was done once a week and home exercises were also prescribed.

For increasing the swing time patients performed concentric contractions of the peroneus brevis and anterior muscle group (tibialis anterior, extensor digitorum longus, and extensor hallucis longus).

For reducing the stance time patients performed the following: for the heel rocker- eccentric contractions of the anterior muscle group; for the second rocker- eccentric contractions of the intrinsic muscles of the foot, peroneus longus and posterior muscle group (tibialis posterior, flexor digitorum longus, flexor hallucis longus, and the gastrocnemius and soleus muscles); for the third rocker-concentric contractions of the posterior muscle group. These movements were meant to improve the load response time on affected and non-affected ankle and single support time on both ankles as well.