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Asymmetry in gait pattern following tibial shaft fractures – a prospective one-year follow-up study of 49 patients☆

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ABSTRACT

Introduction: Despite the high number of studies evaluating the outcomes following tibial shaft fractures, the literature lacks studies including objective assessment of patients' recovery regarding gait pattern. The purpose of the present study was to evaluate whether gait patterns at 6 and 12 months post-operatively following intramedullary nailing of a tibial shaft fracture are different compared with a healthy reference population.
Patients and methods: The study design was a prospective cohort study. The primary outcome measurement was the gait patterns at 6 and 12 months post-operatively measured with a 6-metre-long pressure-sensitive mat. The mat registers footprints and present gait speed, cadence as well as temporal and spatial parameters of the gait cycle. Gait patterns were compared to a healthy reference population.
Results: 49 patients were included with a mean age of 43.1 years (18–79 years). Forty-three patients completed the 12-month follow-up (88%). Gait speed and cadence were significantly increased between the 6- and 12-month follow-up ($P < 0.001$). At 6-month follow-up, patients showed considerable asymmetry in the injured leg compared with the non-injured leg: single-support time 12.8% shorter, swing-time 12.8% longer, step-length 11.9% shorter, and rotation of the foot increased by 32.3%. At the 12-month follow-up, gait asymmetry become almost normalized compared to a healthy reference group.
Conclusion: In patients treated by intramedullary nailing following a tibial shaft fracture, gait asymmetry accompanied with slower speed and cadence are common during the first 6 months and become normalized compared with a healthy reference population between 6 and 12 months post-operatively.

1. Introduction

Fractures of the tibial shaft are recently reported with an incidence of 16.9/100,000/year [1], making it a common injury. The standard treatment is intramedullary nailing due to low rates of complications and high rates of union [2].

Patient-reported outcomes and function following a shaft fracture of the tibia have been reported in several studies [2–6]. Most studies have reported on fracture union, knee pain, joint stiffness, degenerative joint disease, rotational malalignment and limitations in activity of daily living and health-related quality of life (HRQOL) [2–6]. Despite the high number of studies evaluating the outcomes following tibial shaft fractures, the literature lacks studies including objective assessment of patient's recovery regarding functional ability and gait pattern. Gait analysis is important in the evaluation of functional deficit following tibial shaft fractures [6–8]. The LEAP study group [9] have reported significant gait abnormalities and decreased walking speed following severe injuries of the lower extremity and that patients' satisfaction was highly correlated to physical function.

The recovery of gait function and underlying gait variables following fractures of the tibial shaft are poorly understood. Macri et al. [8] evaluated the gait pattern in a group of patients with tibial shaft fractures and reported normal gait function in only 48% of

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patients at 6-month follow-up. Improvement in gait function was associated with the absence of pain at weight-bearing, reduced tenderness at the fracture site, a higher degree of radiographic union and improved functional status. However, studies evaluating specific gait variables (pace, rhythm, variability, injured/non-injured asymmetry, cadence and walking speed) have not been reported previously. Increased knowledge on specific gait characteristics following shaft fractures of the tibia may contribute to improving rehabilitation programmes and patient information during recovery.

The purpose of the present study was to evaluate whether gait patterns at 6 and 12 months post-operatively following intramedullary nailing of a tibial shaft fracture are different compared with a healthy reference population. The explorative aim was to report the association between gait patterns and patient-reported HRQOL.

The hypothesis was that patients treated by intramedullary nailing following a tibial shaft fracture would show gait asymmetry at 6 and 12 months post-operatively compared with a healthy reference population.

2. Patients and methods

2.1. Study design

The study design was a prospective cohort study including all patients treated with intramedullary nailing following a tibial shaft fracture, between September 2012 and June 2014 at Aalborg University Hospital, Denmark. Patients with multi-trauma, bilateral fractures and patients with pathological fractures were excluded. Patients who were unable to participate due to mental disabilities were also excluded.

Basic characteristics regarding age, gender, body mass index (BMI), trauma mechanism, type of trauma and fracture classification were obtained at the time of admission to hospital. All participants gave written informed consent. Complications were reported throughout the study. All patients were examined at the outpatient clinic at 6 and 12 months post-operatively.

The primary outcome measurement was the gait patterns at 6 and 12 months post-operatively. The Danish Data Protection Agency (J. nr. 2008-58-0028) and the local ethics committee (J.nr: N-201-200-11) approved the study, which was performed according to the principles of the Helsinki declaration. The reporting of the study complies with the Strengthening the Reporting of Observational studies in Epidemiology (STROBE) statement [10].

2.2. Gait assessment

Walking ability and gait asymmetries were measured while walking on a pressure-sensitive mat (GAITRite System®) [11]. The mat registers footprints and present gait speed, cadence as well as temporal and spatial parameters of the gait cycle. The method is thoroughly described and validated in a number of studies also including orthopaedic injuries [11–13].

The patients were asked to walk on the (6-m-long) pressure-sensitive mat. The test was performed twice (12-m test). The values from each trial were averaged. The patients walk with a self-selected walking speed from a starting position standing approximately 2 m outside the measuring area, continuing 2 m past the pressure-sensitive mat.

The outcome of the GAITRite system consisted of 21 different gait variables. The mean temporal (step-time, stance time, single- and double-support time, swing-time, cadence and speed) and spatial values (step length, foot angle) were calculated during the 12-m test.

2.3. Selection of gait variables for outcome analysis

Gait speed and cadence represented the general characteristics of the gait pattern. Gait characteristics for the injured and the non-injured leg were evaluated with respect to: single-support, step-length and foot rotational characteristics. The asymmetry between the injured and the non-injured leg was reported as percentage asymmetry (100× Ln(injured/non-injured)) [14]. Furthermore, the variability of the gait cycles was reported as the coefficient of variance (CV) of stance-time (100× SD/mean). Gait patterns from the outcome analysis were compared to a healthy reference population [15].

2.4. Radiological measurements

Fracture classification was performed according to the AO classification [16] and was conducted on preoperatively obtained X-rays. Post-operatively, X-rays of the fractured lower leg were obtained and used to evaluate the bone healing and alignment. The radiological assessments were made on AP and side X-rays.

The evaluation of bone union was defined as: *i*) visible callus formation on at least three of four sides, no visible fracture line and no pain from fracture at weight-bearing and following clinical examination (defined as: union); *ii*) visible callus formation on at least 1 of 4 sides, with a visible fracture line (defined as: partial union); and *iii*) visible fracture lines and no visible callus formation (defined as: no union). The evaluation of union was performed in agreement with other studies' evaluation of union after tibial fractures [17].

2.5. Patient-reported HRQOL

Eq5D-5L is a standardized and validated instrument to assess health outcome [18]. It consists of five dimensions: mobility, self-care, usual activities, pain/discomfort and anxiety/depression, and a self-rated health scale on a 20 cm vertical, visual analogue scale with endpoints labelled 'the best health you can imagine' and 'the worst health you can imagine'. An Eq5D-5L index at 1.0 indicated full health, and 0 denoted death. Eq5D reference data from a general population-based sample in Denmark is available [19].

The authors have previously reported the one-year development in patient-reported HRQOL in patients treated with intramedullary nailing after tibial shaft fractures and found generally lower HRQOL scores compared to an established reference group [30]. The present study used the same study population and Eq5D-5L scores to evaluate the association between HRQOL and asymmetry in patients' gait patterns.

2.6. Statistics

The assumption of normal distribution variables was checked visually by QQ-plots. Continuous data were expressed with mean and standard deviation (SD). Categorical data were expressed as frequencies. Paired *t*-test was considered to test for the difference between the 6- and 12-month follow-up. Asymmetry between injured and non-injured leg is expressed as% asymmetry (100× Ln (injured/non-injured) [14]. At 6 and 12 months post-operatively the Pearson's-test was used to analyse the correlation between Eq5D-5L and% asymmetry between the injured and non-injured leg. A P-value of <0.05 was considered significant. The statistical analysis was performed by SPSS V.22 and STATA V.13.

3. Results

A total of 50 patients were treated for a tibial shaft fracture with intramedullary nailing during the study period. One patient was