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ABSTRACT

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**Comprehensive assessment of patients after treatment of calcaneal fractures using the
Polish modification of the Ilizarov method**

Praca napisana pod kierunkiem
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Introduction:

Despite advances in surgical techniques, the treatment of intra-articular calcaneal fractures—which constitute approximately 75% of all calcaneal fractures—remains controversial due to the high risk of complications and ambiguous functional outcomes. The Polish modification of the Ilizarov method offers an innovative approach that enables fracture stabilization without open reduction, utilizing only a single Kirschner wire inserted into the calcaneus. This study presents an analysis of the effectiveness of this method, including clinical, radiological, and biomechanical assessments, with particular attention to lower limb load distribution and ankle joint function. To date, there has been a lack of scientific reports analyzing the outcomes of calcaneal fracture treatment using the Polish modification of the Ilizarov method.

Objectives:

A comprehensive clinical, biomechanical, functional, and radiological assessment of patients treated for calcaneal fractures using the Polish modification of the Ilizarov technique. A retrospective gait analysis of patients who underwent surgical treatment for intra-articular calcaneal fractures.

Materials and Methods:

The data for our retrospective study came from patients with intra-articular calcaneal fractures treated with the Polish modification of the Ilizarov method in the period between 2021 and 2022.. Three studies included 21 patients (7 women, 14 men), while the clinical and radiological assessment covered 27 patients (2 women, 25 men). Inclusion criteria were: treatment using the Polish Ilizarov stabilizer modification, a minimum follow-up of two years, other lower-limb injuries, lower-limb comorbidities, complete clinical, radiological, and functional documentation, and informed patient consent. Fracture reduction was performed in a closed manner, and the stabilizer consisted of two rings fixed to the lower leg and a half-ring attached to the calcaneus using a single Kirschner wire. The following parameters were assessed: foot function (FFI-R), physical activity (UCLA, Grimby, VAS scales), ankle joint range of motion (dorsiflexion, plantarflexion, inversion, eversion), gait parameters (cadence, speed, step length, stance and swing phases – BTS G-SENSOR), static balance and lower limb weight distribution (FreeMED MAXI pedobarographic platform), and radiological

parameters (Böhler's angle, Gissane's angle, inflection angle). The study group was compared with a control group of 19–21 healthy volunteers matched for sex and BMI.

Results:

Patients showed a significantly longer path of the center of gravity (1307.31 mm) compared to the control group (896.34 mm; $p = 0.038$), with no differences in the area of center of gravity ($p = 0.324$). The percentage weight distribution between limbs was symmetrical; however, significantly lower forefoot loading was observed in the operated limb (19.22%) compared to the non-operated limb (25.33%; $p = 0.039$) and the non-dominant limb in the control group (23.66%; $p = 0.026$). Post-treatment, significant improvements in activity levels were recorded: the UCLA scale increased from 2 to 5 ($p = 0.048$), Grimby from 2 to 5 ($p = 0.023$), and the FFI-R score decreased from 292 to 127 points ($p = 0.013$). Ankle range of motion in the operated limb was limited: dorsiflexion 20° vs. 40° ($p = 0.007$), plantarflexion 15° vs. 30° ($p = 0.007$), inversion 5° vs. 15° ($p = 0.039$). Gait analysis revealed a shorter stance phase in the operated limb (59% vs. 64%; $p = 0.043$) and a shorter single-support phase (36% vs. 42%; $p = 0.025$). Moreover, the swing phase of the healthy limb in post-operative patients was shorter (36% vs. 40% in the dominant limb of the control group; $p = 0.02$). Pain, as assessed on the VAS scale, averaged 2.3 (range 0–6), and 96% of patients expressed satisfaction with the treatment. Radiological parameters significantly improved: Böhler's angle increased from 5.5° to 28.5° , Gissane's angle from 119° to 143° , and the inflection angle decreased from 160° to 145° (all $p < 0.001$). The complication rate was low (18.5%) and limited to superficial infections around the Kirschner wires.

Discussion:

Intra-articular calcaneal fractures pose a significant therapeutic challenge due to the complex anatomy and high risk of complications. The use of the Polish modification of the Ilizarov method, based on closed reduction and external fixation with a single Kirschner wire, offers a minimally invasive alternative to conventional surgical techniques. This method enables anatomical restoration of the calcaneus and reestablishment of balance and symmetrical lower limb weight distribution, while minimizing risks such as infection or soft tissue necrosis. The study demonstrated improvements in radiological parameters, including Böhler's and Gissane's angles, as well as a reduction in pain intensity. Reduced pain levels, decreased need for analgesics, and patients' willingness to choose the same treatment again reflect a high level of satisfaction. Most patients showed improved limb function, increased physical

activity, and normalization of gait parameters. While some limitations in ankle range of motion and incomplete postural control normalization were noted, they did not significantly impact overall functional outcomes. Due to its low complication rate, shorter hospitalization time, and allowance for early limb loading, the Ilizarov method may be considered an effective, safe, and clinically justified treatment option for intra-articular calcaneal fractures.

Conclusions

The Polish modification of the Ilizarov method is an effective and safe treatment option for intra-articular calcaneal fractures. It enables precise fracture reduction and stabilization while minimizing the risks associated with open surgical techniques. Most patients regain good functional capacity, and gait parameters and load distribution closely approximate those of healthy individuals. These findings support the use of the Ilizarov method as a reliable and safe alternative for the treatment of intra-articular calcaneal fractures.