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Case Reports and Series

An Evaluation of Surgical Functional Reconstruction of the Foot Using Kinetic and Kinematic Systems: A Case Report

Elena Irene Jordán-Palomar, MD [1], Etelvina Javierre, PhD [2], José Rey-Vasalo, MD [3], Víctor Alfaro-Santafé, MD [4], María José Gómez-Benito, PhD [5]

[1] *Surgeon, Hospital Universitario Miguel Servet, University of Zaragoza, Saragossa, Spain*
[2] *Associate Professor, Centro Universitario de la Defensa, Academia General Militar, Zaragoza, Spain*
[3] *Surgeon, Servicio de Cirugía Plástica y Reconstructiva, Complejo Hospitalario de Navarra, Pamplona, Spain*
[4] *Podiatrist, Podoactiva S.L., Calle Padre Huesca, Huesca, Spain*
[5] *Associate Professor, Department of Mechanical Engineering, Facultad de Ingeniería y Arquitectura, Aragón Institute of Engineering Research (I3A), Universidad de Zaragoza, Zaragoza, Spain*

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ABSTRACT

Most pedobarographic studies of microsurgical foot reconstruction have been retrospective. In the present study, we report the results from a prospective pedobarographic study of a patient after microsurgical reconstruction of her foot with a latissimus dorsi flap and a cutaneous paddle, with a 42-month follow-up period. We describe the foot reconstruction plan and the pedobarographic measurements and analyzed its functional outcome. The goal of the present study was to demonstrate that pedobarography could have a role in the treatment of foot reconstruction from a quantitative perspective. The pedobarographic measurements were recorded after the initial coverage surgery and 2 subsequent foot remodeling procedures. A total of 4 pedobarographic measurements and 2 gait analyses were recorded and compared for both the noninvolved foot and the injured foot. Furthermore, the progress of the reconstructed foot was critically evaluated using this method. Both static and dynamic patterns were compared at subsequent follow-up visits after the foot reconstruction. The values and progression of the foot shape, peak foot pressure (kPa), average foot pressure (kPa), total contact surface (cm^2), loading time (%), and step time (ms) were recorded. Initially, the pressure distribution of the reconstructed foot showed higher peak values at nonanatomic locations, revealing a greater ulceration risk. Over time, we found an improvement in the shape and values of these factors in the involved foot. To homogenize the pressure distribution and correct the imbalance between the 2 feet, patient-specific insoles were designed and fabricated. In our patient, pedobarography provided an objective, repeatable, and recordable method for the evaluation of the reconstructed foot. Pedobarography can therefore provide valuable insights into the prevention of pressure ulcers and optimization of rehabilitation.

The plantar foot consists of highly specialized tissues with fibrous septa that anchor the skin to the underlying fascia to avoid vertical and transversal displacements. The correct and stable position for locomotion is achieved by proprioceptive sensitivity and muscular response. These tissues are arranged to support one's weight and provide balance under static and dynamic conditions. The load supported by the plantar foot is concentrated mainly on the heels and metatarsal heads. This load can be modified by velocity, body weight, age, and osteoarticular or neurologic pathologic features. With injury to the plantar foot, it is necessary to carefully evaluate the coverage, mechanical stress, and patient characteristics and consider realistic surgical options. Good diagnosis, treatment, and follow-up examinations are essential to provide the patient with the best possible medical care. Normally, injuries to the plantar foot will not lead to the death of the patient; however, they involve long hospital stays, numerous sequelae, and high economic costs to the health care system. In the United States, the estimated average costs when this type of injury affects 1 or both feet are $21,000 and $39,000, respectively (1).

Injuries to the foot can be difficult to repair, depending on the area involved. Heel tissue reconstruction is complex, because no specific flaps have been biologically designed to cover this particular area. Many surgical options have been introduced, including musculocutaneous flaps, fasciocutaneous flaps, free flaps with or without a

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Address correspondence to: Elena Irene Jordán-Palomar, MD, Surgeon, Hospital Universitario Miguel Servet, University of Zaragoza, Saragossa 31008, Spain.
E-mail address: aneleum@gmail.com (E.I. Jordán-Palomar).

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skin paddle, and perforator flaps (2). Although the criteria for the best type of reconstruction remain unclear (3,4), agreement has been reached that when attempting reconstruction, below-the-knee amputation should be avoided (5). Meyer-Marcotty et al (6) concluded in a retrospective study of 23 patients (with a single measurement per patient) that the long-term results will depend on the exposure of the reconstructed area to pressure. They reported that the ulceration ratio increased from 11% in non-weightbearing area reconstruction cases to 32% in weightbearing area reconstruction cases. They used pedobarographic records to show statistically significant differences in the peak pressure on the weightbearing zone between the reconstructed feet and noninjured feet. Moreover, the loss of sensitivity in the affected foot tissues caused scratches, high pressure, bad positions, deformities, and neuropathic ulcers. These pathologic features were the main cause of surgical revision.

In daily practice, postoperative follow-up monitoring of foot reconstruction has often been performed by direct observation or static imaging methods, such as radiography or computed tomography. However, since the first reports by Goldberg et al (7), who recorded plantar footprints by soaking the plantar foot with mineral oil, asking the patient to step onto an absorbent type of paper, and drawing the resulting contour on the paper with a marking pen, more objective and evaluator-independent methods have been sought. Villa Moreno et al (8) studied alterations in weightbearing patterns and gait using kinetic, kinematic, and electromyographic analyses to establish benchmarks for future comparisons.

Öztürk et al (9) used similar pedobarographic methods to evaluate the functional outcomes after lower limb reconstruction in patients who had sustained serious injuries after landmine explosions. The investigators retrospectively compared 72 cases of plantar foot reconstruction at a single point with a group of 20 healthy patients (9). Dynamic pressure distribution tests revealed significantly higher pressure and loads on the injured feet. Three-dimensional motion analyses showed a restricted range of motion of the ankle joints in the injured extremities. This is the longest series of cases to document the long-term functional results of patients injured by landmines and treated with free muscle flaps. The investigators concluded that reconstructive options should be preferred over amputation procedures, whenever possible, in cases of extensive tissue loss caused by landmine explosions (9).

The aim of the present study was to report a prospective model to record and evaluate the functional results before and after foot surgery. We describe a single clinical case in great detail. To the best of our knowledge, pedobarography has not been previously used to evaluate functional outcomes after foot surgical reconstruction and to plan rehabilitation. The results were also used to design specific insoles for the patient. These were fabricated using rapid prototyping to compensate for the pressure distribution differences in the plantar foot.

Case Report

The present work describes the case of a 32-year-old white female, with no relevant surgical or personal history, who had experienced a motorbike traffic accident in November 2009. The timelines of the different surgical procedures and the acquisition of biomechanical data are presented in Fig. 1 and the Table. When crushed by the side of the motorbike, the patient's right foot had sustained serious injuries; however, her other injuries were minor. They included superficial abrasions and bruises on the arms. At hospital admission, the patient presented with a Lisfranc fracture dislocation, a fifth metatarsal fracture, and subfascial degloving of the plantar foot with a distal pedicle. She was admitted to the orthopedic surgery department and fixation of the fractures and wound dressing changes were performed. The patient had no other serious injuries. After 6 days, the patient had developed a posterior tibial artery thrombosis, which caused cutaneous, fascial, and fat tissue necrosis of the heel and plantar arch area (Fig. 2).

The plastic surgery department was then consulted for debridement and coverage of the involved areas. The patient was informed and provided written consent for her participation in a prospective study. We evaluated the preoperative and postoperative functional results of plantar foot reconstruction through

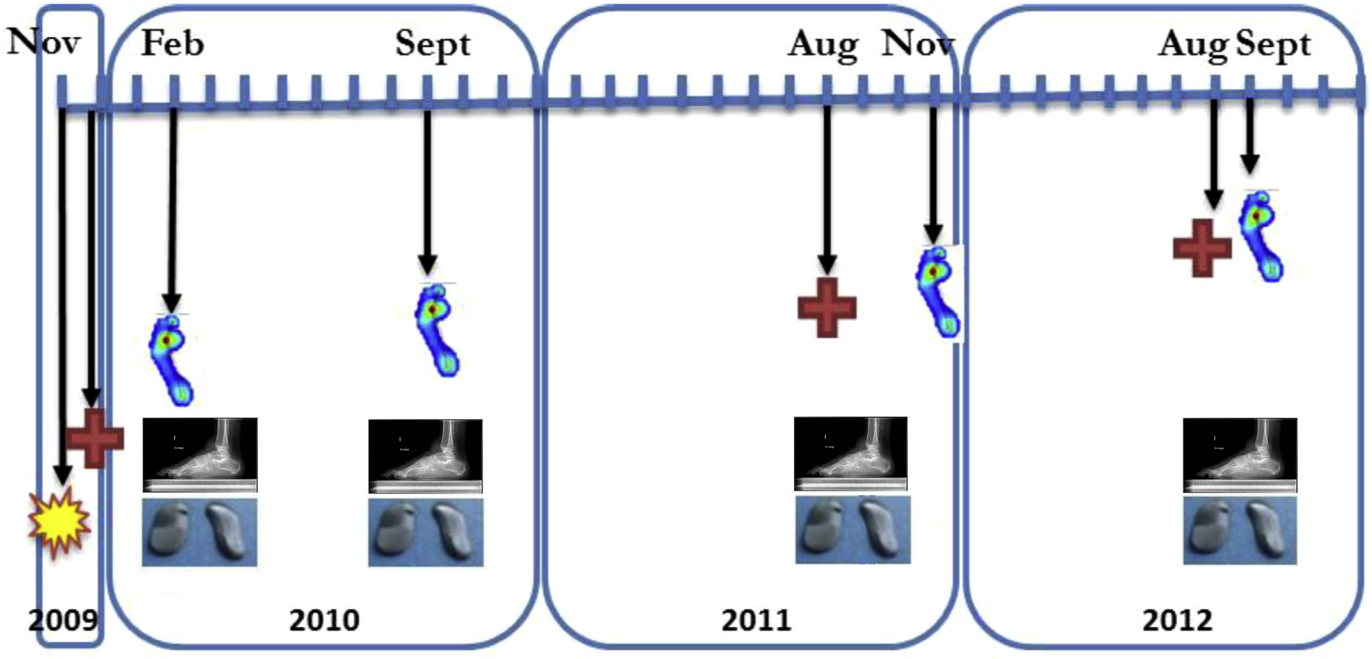

Fig. 1. Timeline of patient follow-up care. Red crosses indicate surgical intervention. Photograph enlarged above.