PEDOBAROGRAPHIC DIAGNOSIS OF PLANTAR PRESSURE DISTRIBUTION IN PATIENTS HAVING CALCANEAL FRACTURES

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Abstract
Being quite rare, fractures of the calcaneus have not been a frequent subject of studies, although they are interesting as regards various approaches to the treatment, a long period of recovery and the possibility of permanent deformities. The authors’ intention was to examine the distribution of plantar pressures in patients with calcaneal fractures using the capacitor systems for the measurement of plantar pressures during walk on a platform (the Emed measuring system) and while wearing shoes with arch supports and in-built sensors (the Pedar measuring system). In case of fresh fractures of the calcaneus, the heel is the site of major loading, whereas in case of old calcaneal fractures the foot loading is normal with the heel being spared during walk or peak-pressures appearing on unusual sites.

Keywords: calcaneal fractures, pressure measurement

1. Introduction
Fractures of the calcaneus are fractures with perhaps the worst reputation as compared to all other fractures occurring in humans. A traditional approach to the treatment of calcaneal fractures by reduction, fixation and maintenance of function is most often neglected and considered an ineffective method of treatment so that the majority of surgeons apply conservative methods in order to achieve the best possible results.
Calcaneal fractures are extremely rare injuries and most of the collected serial data report an overall incidence rate of 2.0 - 2.5%. Fractures of the calcaneus have been known and recognized for centuries. The fact that this fracture occurs due to compression was known as early as 1839 (Norris) and 1847 (Malgaigne). Morestin (1902) was the first one to recognize the fracture line running "upwards and downwards, downwards anterior and upwards posterior", but Boehler (1931) was the first one who presented a classification of fracture types according to their radiographic appearance.
Falls form heights are responsible for the vast majority of calcaneal fractures. The assumption that the severity of fracture is directly proportional with the height of the fall has not been proved in practice. The exact nature of a fall, the patient weight and the presence of osteoporosis are of immense importance.
The second mechanism of injury is a force acting from below when the subject is immobile as in frontal motor vehicle collisions with driver's heels being crushed by the bottom of the vehicle. The same mechanism is present in mine and bomb explosions, etc.
In males, 72% of fractures occur under the age of 50 years. In females, calcaneal fractures are most frequent in the group over 65 years of age, whereas only 38% of fractures occur under the age of 50 (Burke, 1983). Diagnosis of calcaneal fractures should not be difficult. However, these fractures are often overseen. This happens partly due to the fact that a fracture need not be severe enough to deform the shape of the calcaneus and partly because it may be just one of many other multiple injuries. 2-10% of lumbar spine fractures are associated with fractures of the calcaneus.
It has been widely accepted that fractures of the calcaneal ends require immobilization and sporadically internal fixation. As for calcaneal fractures with dislocations, the methods of treatment can be divided into six main categories:
1. immobilization without reduction
2. manual reduction
3. instrumental reduction
4. primary arthrodesis
5. early mobilization without weight-bearing or attempted reduction
6. open reduction with bone grafting.
Although rare, calcaneal fractures cause a large percentage of working disability. It is evident that intensive treatment, early mobilization and physical therapy can yield good results, even if the foot remains permanently deformed. Immobilization in a plaster cast for more than 6 weeks inevitably leads to much poorer results. Complete recovery after such an injury can last for two or more years; late degenerative changes are mostly unknown despite x-rays; there are very few or no indications for arthrodesis1-3).
Plantar pressures can be measured by various systems of platforms and systems designed to monitor the pressures in the footwear. The best known systems of platforms are those with built-in sensors that change resistance, color or charge depending upon the size of pressure. Leading systems for the monitoring of pressures in the footwear are those with variable resistors (rheostatic systems) or variable conductors, namely the so called capacitor systems. It is typical for all systems that data can be processed and saved using a computer4).
2. Methods

The aim of our study was to examine the distribution of plantar pressures in patients having calcaneal fractures. In our study, we have used two systems for the evaluation of plantar pressures in patients with calcaneal fractures. The systems differ in the number of sensors as well as in the degree of mobility. Examinations were performed at the Orthopaedic polyclinic "Kinematika" in Zagreb, on the systems MiniEmed and Pedar (by Novel). MiniEmed is a walking platform with built-in sensors and the sensor field located at the same level as the platform. The platform is connected to a computer with a program for data collection and evaluation. The pressure-sensitive field consists of a matrix with 3 sensors per square centimeter, which allows collection of highly precise data on the magnitude of plantar pressure. The system takes static and dynamic prints. A dynamic print consists of 22 images, which allows monitoring of specific segments of the contact between the plantar surface and the ground. In this way, it is possible to determine the segment of greatest contact pressure, the foot portion loaded by the greatest pressure and the direction of the line that connects the points of peak-pressure with a specific segment, the so called "gait-line" (see Fig. 3).

Following taking of dynamic footprints (footprints during walk) patients are asked not to aim at the sensor field and not to slow down or stop before or at the moment of contact with it. Static footprints (during standing) are also taken.

PEDAR is a system for monitoring of the plantar pressure in the shoe. It has flexible insoles/arch supports with 85 condenser transducers attached to the device via cables, and the device itself is connected to the computer. The PEDAR system is supplied with the adequate software support, which allows processing of data on individual segments and changes in the pressure. This system has found application in the diagnostics of loading of the foot in the footwear, which is highly significant for conditions in which footwear is responsible for the development of certain pathological changes, such as trophic ulcers in paraesthetic and diabetic patients. The system has also been applied for the control of orthopaedic insoles quality.

With regard to the bad reputation of calcaneal fractures, we have used the MiniEmed and Pedar systems for clinical analysis of plantar pressures and gait disorders in patients with either relatively fresh calcaneal fractures or unhealed old fractures of the calcaneus. Both systems have found application in the identification of early and late complications associated with calcaneal fractures.

3. Results

Pedobarographic analysis of both static and dynamic footprints of patients with relatively fresh fractures of the calcaneus has shown that the loading is greatest in the heel, whereas the anterior portion of the foot remains almost unused during walk (walk with crutches and

leaning on the whole foot length without the gait phases - see the figure 1).

Fig.1 Common plantar pressure distribution in patient having fresh calcaneal fracture.

In patients with healed fractures of the calcaneus, the pedobarographic analysis shows normal loading, i.e. the loading similar to the loading in healthy patients having no calcaneal fractures (see Fig. 2). Sometimes, dynamic footprints taken in these patients may show a sparing of the heel, which is particularly noted in patients having old injuries of the heel inflicted by fragments of explosive devices.

Fig.2 3D pedobarographic diagram of female patient with old fracture of the right calcaneus

Pedobarographic analysis performed in patients having malunited comminutive fractures of the calcaneus shows that greater loading is present on certain sites, i.e. peak-pressures are present on malunion sites.
4. Discussion

Although rare, fractures of the calcaneus are highly significant as they are often associated with permanent deformities, relatively long periods of treatment and a slow recovery.

The majority of our 14 patients examined using the Emed and Pedar measuring systems, were females between 40 and 50 years of age, and fractures were mostly due to falls from heights, were traffic-related accidents or war-related foot injuries inflicted by fragments of explosive devices.

Pedobarographic analysis of fresh fractures of the calcaneus has shown that during walk the greatest loading is recorded in the heel and that the anterior portion of the foot is almost not used at all, which can be attributed to the use of crutches. Namely, while walking on crutches the patient leans mostly on the heel as long a the foot is immobilized. This habit remains for a while after the immobilization has been removed, although the patient develops pains after this initial weight-bearing of the heel, and the pressure along with loading is shifted towards the anterior foot portion.

Pedobarographic analysis performed in patients having healed fractures of the calcaneus shows normal loading parameters, namely the loading is similar to that present in healthy subjects who have not sustained calcaneal fractures. This proves that properly healed fracture of the calcaneus leaves no sequelae as regards the function of the foot.

In patients having old and unhealed fractures of the calcaneus, the analysis of dynamic footprints shows the presence of spared heel, which is particularly prominent in case of old heel injuries inflicted by fragments of explosive devices. If the fracture has not healed well, the heel is still spared during the gait, which is clearly visible in the pattern of plantar pressure distribution. If a portion of the calcaneus is missing, it is clear that pressures cannot be distributed as usual.

Pedobarographic analysis of patients’ gait after comminutive fractures that have not healed properly or where resorption of fragments has occurred shows the presence of greater loading on certain sites - the so called sites of peak-pressures.

With regard to a small number of patients and a rather short period of study, we are not able to compare the distribution of plantar pressures in the same patient shortly after injury, then following immobilization removal and after a period of at least two years (the minimum time needed for full recovery). Based on our present results, we may assume that the distribution would be significantly different, which will probably be shown by future studies.

5. Conclusion

Fractures of the calcaneus are highly interesting subject due to controversies as regards the methods of treatment, a long period of recovery and the nature of associated complications. Pedobarographic diagnosis of plantar pressure distribution in patients having calcaneal fractures has shown the following: in case of fresh fractures the heel is exerted to greater loading due to the use of crutches and the weight-bearing of the heel during immobilization; in old fractures the loading is normal with the exception of heel injuries caused by fragments of explosive devices where the heel is spared during the gait; in case of malunited comminutive fractures peak-loadings, i.e. peak-pressures are noted on unusual sites in the foot.

Fig 3. Novel software provides accurate evaluation of each region of the foot

References

