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Radiological results and clinical complications after calcaneal articular fracture surgical treatment using minimally invasive percutaneous fixation

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Abstract: The choice of method for surgical treatment of articular calcaneal fractures remains problematic due to the potential complications and difficulty in restoring loss of functional status, anatomical geometry and congruence of joint surfaces. The preferred method of surgical treatment for these injuries, among others, is still minimally invasive percutaneous fixation. The aim of this study was to evaluate the radiological results of articular calcaneal fractures surgical treatment using a minimally invasive percutaneous fixation and to determine the prevalence of complications in early and long-term observation. Radiological results of surgical treatment of 82 patients operated using minimally invasive percutaneous fixation were analyzed. The radiological results were based on Böhler angle and varus angle using criteria according to Harnroongroj and Golec. Postoperative complications were registered in a 3 months follow-up (early observation) and after 6 months (long-term observation). Patients with tongue-type fractures had significantly better surgical outcomes than patients with depression-type fractures. Displacements of bone fragments in articular calcaneal fractures visualized radiographically by the changes of Harnroongroj *et al.* angle do not constitute a serious surgical problem and are easily

repositioned and stabilized, as opposed to displacements resulting in changes in the value of the Böhler angle. The most common postoperative complications were local inflammatory reactions at the point of entry of fixation material and thromboembolic complications. Results of surgical treatment of articular fractures of the calcaneus using a minimally invasive percutaneous fixation are good and satisfactory in majority of patients suggesting that this method constitutes proper choice of treatment.

Key words: intra-articular calcaneal fractures, complications, minimally invasive surgery.

Introduction

The choice of the method for surgical treatment of articular calcaneal fractures remains a matter of controversy and a lively polemic in terms of its effectiveness both in the early and long-term clinical observation, minimizing the risks of various complications and restoring loss of functional status, anatomical geometry and congruence of joint surfaces [1–3]. This state is due to the complex morphology of articular calcaneal fractures, especially joint depression fractures. In some patients they result in irreversible destruction of the articular surface of the talocalcaneal, talocalcaneonavicular, and the tibiofibular joints [4–6] and the inevitable development of degenerative changes, which may be accompanied by dystrophic changes in the whole foot and the consequent chronic pain syndrome and gait deficiency [5]. It seems that the preferred method of surgical treatment for these severe injuries, among others, is still minimally invasive percutaneous fixation [7–9].

The aim of this study was to determine the radiological results of surgical treatment of articular fractures of the calcaneus using a minimally invasive percutaneous fixation and to address the following questions:

1. What are the radiological results of surgical treatment of articular fractures of the calcaneus using a minimally invasive percutaneous fixation in the early and long-term observation, depending on the gender and based on accepted evaluation criteria?
2. Which of the displaced bone fragments of articular calcaneal fractures are issues for surgery in early and long-term observation?
3. What are the most common complications of surgical treatment of articular fractures of the calcaneus using a minimally invasive percutaneous fixation in early and long-term observation?

Materials and methods

Study group characteristics

This study was carried out based on the material covering the period from 1990 to 2012. It was divided according to gender, age, type of fracture based on the classification by Essex-Lopresti [10], the method of fixation of bone fragments and registered complications.

The study group consisted of 82 patients operated on due to articular calcaneal fractures and included 68 males (83%) and 14 females (17%). The age on the day of surgery ranged from 34 to 67 years and averaged 48 years. An average age for a man was 41 years (range 34 to 53 years) and for a woman was 64 years (range 61 to 67 years). The right calcaneal fracture was diagnosed in 47 men (57.4%) and the fracture of the left calcaneus was diagnosed in the remaining 21 men (25.6%). In women, right calcaneal fractures were seen in eight of them (9.7%) and left calcaneal fractures in the remaining six (7.3%). Thus, a total of 55 (67.1%) right calcaneal fractures and 27 (32.9%) left calcaneal fractures were included in the study. Assuming the classification by Essex-Lopresti [10], the tongue-type fracture was observed in 26 men (31.7%) and the depression-type fracture in 42 men (51.3%). In women, the tongue-type fracture was diagnosed in 3 of them (3.6%) and the depression-type fracture in 11 (13.4%). In total, the tongue-type fracture was identified in 29 operated patients (35.3%) and the depression-type fracture in 53 (64.7%).

The following causes of fractures were reported: fall from a height of less than 2 meters in 19 patients (23.1%), a fall from a height of over 2 meters in 39 patients (47.7%), a traffic accident in 16 patients (19.5%), and abnormal landing during a parachute jump in 8 individuals (9.7%). The treatment of tongue-type fractures involved surgical fixation using the Westhues technique or Westhues technique with additional stabilization of bone fragments with Kirschner wires. The Westhues method was used in 19 men (23.2%) and the Westhues method with additional stabilization with Kirschner wires was used in 7 men (8.6%). In the group of patients with joint depression fracture, the Westhues method combined with additional stabilization of bone fragments with Kirschner wires was used in 27 men (32.9%) and the method of percutaneous fixation of bone fragments with Kirschner wire as suggested by Rapala [11] was utilized in 15 men (18.3%). Tongue-type fractures were treated with Westhues method with Kirschner wires in 3 women (3.6%). In the treatment of depression-type fractures, the same method was used in 4 women (4.8%) and the Rapala method in the remaining seven (8.5%).

The patients enrolled in the study were operated on in 2 to 6 days after sustaining the injury. The surgery was performed under spinal or epidural anesthesia. In patients who underwent fixation of bone fragments using Westhues method, the operated limb was immobilized in a short leg cast for a period of 6 to 8 weeks. During this period

thromboembolic prophylaxis (Fraxiparine, Lovenox) and antimicrobial prophylaxis (Zinacef, Amikacin, Tarcefandol) were employed in accordance with current guidelines. Steinmann pin and Kirschner wires were removed from the calcaneus on the same date as the cast.

Radiological and clinical assessment methods

The radiological results were based on the criteria by Golec *et al.* [12] and Harnroogroja *et al.* [13] with modification by Golec *et al.*

The 2003 criteria by Golec *et al.* [12], are based on the measurement of the Böhler angle on radiograms made in the lateral projection on the day of admission to hospital, 3 days after the surgery and after 3, 6 and 12 months. Our modification to the above criteria involves assigning a specific grade to the range of the Böhler angle, as illustrated in Table 1.

Table 1. Grade criteria based on the Böhler angle.

Böhler angle value	Grade
40 to 35°	Very good (VG)
34 to 30°	Good (G)
29 to 20°	Satisfactory (S)
19 to 10°	Poor (P)
9° to negative values	Very poor (VP)

Criteria by Harnroogroja *et al.* [13] allow for the assessment of the degree of displacement of the calcaneal fragments on radiograms made in the Harris projection (penetrated axial projection).

This method is based on the selection of the XY axis, which runs from the calcaneal tubercle in line with the course of the trabeculae, and the malleolar line (II) coinciding with the posterior articular surface of the calcaneus. Both lines intersect at an angle of 90° giving the correct image, which is illustrated on Figure 1.

The following values of this angle, with the assessment of the radiological results in the situation of displaced bone fragments were proposed, as listed in Table 2. These measurements were based on the analysis of axial calcaneal X-rays, taken on the date of admission to the hospital, 3 days after the surgery and 3, 6 and 12 months after the procedure.

The method for the analysis of complications of surgical treatment of articular calcaneal fractures was based on their registration in a 3 months follow-up (early observation) and after 6 months (long-term observation).



Fig. 1. Radiogram of the calcaneus in the penetrated axial projection with a normal varus angle, according to Harnroongroj *et al.* [10].

Table 2. Grade criteria of the radiological results of surgical treatment of articular calcaneal fractures based on the assessment of the varus angle of displaced bone fragments using Harnroongroj *et al.* method with modification by Golec *et al.*

Varus angle value of displaced bone fragments [°]	Grade
90°	Very good (VG)
89 to 85°	Good (G)
84 to 80°	Satisfactory (S)
79 to 75°	Poor (P)
below 75°	Very poor (VP)

Results

Complications in males in early observation

The following complications were reported in males after surgical treatment of tongue type articular calcaneal fractures of using Westhues fixation method: deep vein thrombosis, local inflammatory reactions at the point of entry of Steinmann pin at the calcaneal tubercle and its destabilization. Deep vein thrombosis of the shin was diagnosed in 2 patients (3%) operated using this method, local inflammation of the skin at the point of entry of the Steinmann pin at the calcaneal tubercle was seen in

4 patients (5.9%), and the destabilization of the fixation in 1 patient (1.4%). A total of 7 men (10.3%) undergoing the Westhues fixation experienced complications in the early observation.

The following complications were reported in males undergoing Westhues fixation with additional stabilization of bone fragments with Kirschner wires: deep vein thrombosis of the shin in 3 of them (4.4%) and local inflammation at the point of entry of Steinmann pin in 3 of them (4.4%). In total, 6 males (8.8%) undergoing surgery using this method experienced complications in the early observation. In the same period of observation in men who were treated surgically for depression-type fractures using Westhues method with additional stabilization of bone fragments with Kirschner wires, the following complications were observed: deep vein thrombosis of the shin in 2 (3%) and the local inflammation of the skin at the point of entry of fixation material in 4 patients (5.9%). The utilization of Rapała method in this group of patients resulted in a deep vein thrombosis of the shin in 3 men (4.4%), and local inflammation of the skin in the place of entry of fixation material in 5 (7.3%). A total of 12 males (20.6%) treated for depression-type fracture experienced complications in the early observation.

A total of 27 men treated with abovementioned methods experienced complications in the early observation, which represents 39.7% of men and 32.9% of the test group. The complications included venous thrombosis in 10 men (14.8%), topical inflammatory complications in 16 men (23.5%) and one destabilization of fixation (1.4%).

Deep vein thrombosis of the shin coincided with local inflammatory reaction of the skin in 7 men (10.3%) in the early observation. In this group there were four men (5.9%) with depression-type fractures treated with Westhues method in combination with additional stabilization of the bone fragments with Kirschner wires, the next two (3%) treated for depression-type fractures with Rapała method and one (1.4%) treated for tongue-type fracture with Westhues method.

Complications in females in early observation

Women after surgical treatment of tongue-type fractures with Westhues method in combination with additional stabilization of bone fragments with Kirschner wires experienced deep vein thrombosis of the shin, which occurred in 2 of them (14.3%). In women treated surgically for depression-type fractures with Westhues method in combination with additional stabilization of bone fragments with Kirschner wires, deep vein thrombosis of the shin was observed in 2 of them (14.3%). The same complication was seen in 3 women (21.4%) and local inflammation of the skin at the place of entry of fixation material in 4 women (28.6%) treated with Rapała method. Deep vein thrombosis of the shin coincided with local inflammatory reaction of the

skin at the site of entry of Kirschner wires in 6 women (42.8%), including 4 patients (28.6%) with depression-type fractures treated with Westhues method with additional stabilization of the bone fragments with Kirschner wires and in 2 patients (14.3%) treated for the same reason with Rapała method.

Complications in males in long-term observation

The following complications were reported in men operated due to articular fractures of the calcaneus in the long-term observation: post-thrombotic syndrome of the shin, local skin necrosis at the point of entry of fixation material that developed due to earlier inflammatory changes and Sudeck syndrome.

Post-thrombotic syndrome of the shin was diagnosed in 3 men (4.4%), including 1 (1.4%) in which it coexisted with the local skin necrosis at the point of entry of Steinmann pin that has developed on the surface of pre-existing inflammatory changes. The patient underwent surgery using Westhues method with additional stabilization of bone fragments with Kirschner wires, because of a depression-type fracture.

Sudeck syndrome was diagnosed in 2 patients (3%) operated on because of the depression-type fractures, including 1 using Westhues method with additional stabilization of bone fragments with Kirschner wires and 1 using Rapała method.

Complications in females in long-term observation

In long-term observation 2 women (14.3%) who underwent surgical treatment of tongue-type fractures using Westhues method in combination with additional stabilization of bone fragments with Kirschner wires experienced a post-thrombotic syndrome of the shin. In women treated surgically for depression-type fractures using the same method, post-thrombotic syndrome of the shin was observed in one of them (7.1%) and using Rapała method in 2 of them (14.3%). In long-term observation Sudeck syndrome was seen in 2 women (14.3%) treated for tongue-type fractures using Westhues method with additional stabilization of bone fragments with Kirschner wires. There were no inflammatory complications in women in the long-term observation.

Radiological results

Radiological results in males based on Böhler angle are presented in Tables 3–6 depending on the type of the fracture and the methods used for surgical stabilization.

Radiological results in females based on Böhler angle are presented in Tables 7–9 depending on the type of the fracture and the methods used for surgical stabilization.

Table 3. Radiological results in men based on Böhler angle in tongue-type fractures of the calcaneus treated with Westhues method (n = 19; 23.2%).

Böhler angle	Result depending on the type of fracture and the method				
	Tongue-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	12	7
3 days after surgery	6	13	–	–	–
3 months after surgery	5	11	3	–	–
6 months after surgery	5	11	3	–	–
12 months after surgery	4	11	4	–	–

Table 4. Radiological results in men based on Böhler angle in tongue-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 7; 8.6%).

Böhler angle	Result depending on the type of fracture and the method				
	Tongue-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	4	3
3 days after surgery	3	4	–	–	–
3 months after surgery	3	4	–	–	–
6 months after surgery	2	3	1	–	–
12 months after surgery	2	3	1	–	–

Table 5. Radiological results in men based on Böhler angle in depression-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 27; 32.9%).

Böhler angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	8	19
3 days after surgery	–	9	12	4	2
3 months after surgery	–	6	13	5	3
6 months after surgery	–	5	14	5	3
12 months after surgery	–	5	14	5	3

Table 6. Radiological results in men based on Böhler angle in depression-type fractures of the calcaneus treated with Rapafa method (n = 15; 18.3%).

Böhler angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	7	8
3 days after surgery	–	9	2	4	–
3 months after surgery	–	7	3	4	1
6 months after surgery	–	7	3	3	2
12 months after surgery	–	7	3	3	2

Table 7. Radiological results in women based on Böhler angle in tongue-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 3; 3.6%).

Böhler angle	Result depending on the type of fracture and the method				
	Tongue-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	3	–
3 days after surgery	3	–	–	–	–
3 months after surgery	2	1	–	–	–
6 months after surgery	2	1	–	–	–
12 months after surgery	2	1	–	–	–

Table 8. Radiological results in women based on Böhler angle in depression-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 4; 4.8%).

Böhler angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	3	1
3 days after surgery	2	2	–	–	–
3 months after surgery	1	2	1	–	–
6 months after surgery	1	2	1	–	–
12 months after surgery	1	2	1	–	–

Table 9. Radiological results in women based on Böhler angle in depression-type fractures of the calcaneus treated with Rapała method (n = 7; 8.5%).

Böhler angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	3	4
3 days after surgery	–	–	2	2	3
3 months after surgery	–	–	2	1	4
6 months after surgery	–	–	2	1	4
12 months after surgery	–	–	2	1	4

Radiological results in males based on Harnroongroj *et al.* angle in own modification are presented in Tables 10–13 depending on the type of the fracture and the methods used for surgical stabilization.

Table 10. Radiological results in men based on Harnroongroj *et al.* angle in tongue-type fractures of the calcaneus treated with Westhues method (n = 19; 23.2%).

Harnroongroj <i>et al.</i> angle	Result depending on the type of fracture and the method				
	Tongue-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	2	13	4
3 days after surgery	2	15	2	–	–
3 months after surgery					
6 months after surgery					
12 months after surgery					

Table 11. Radiological results in men based on Harnroongroj *et al.* angle in tongue-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 7; 8.6%).

Harnroongroj <i>et al.</i> angle	Result depending on the type of fracture and the method				
	Tongue-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	5	2
3 days after surgery	5	2	–	–	–
3 months after surgery	4	3	–	–	–
6 months after surgery	4	3	–	–	–
12 months after surgery	4	3	–	–	–

Table 12. Radiological results in men based on Harnroongroj *et al.* angle in depression-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 27; 32.9%).

Harnroongroj <i>et al.</i> angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	9	18
3 days after surgery	–	10	12	4	1
3 months after surgery	–	9	13	4	1
6 months after surgery	–	9	13	4	1
12 months after surgery	–	9	13	4	1

Table 13. Radiological results in men based on Harnroongroj *et al.* angle in depression-type fractures of the calcaneus treated with Rapała method (n = 15; 18.3%).

Harnroongroj <i>et al.</i> angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	9	6
3 days after surgery	–	10	3	2	–
3 months after surgery	–	8	5	1	1
6 months after surgery	–	8	5	1	1
12 months after surgery	–	8	5	1	1

Radiological results in females based on Harnroongroj *et al.* angle in own modification are presented in Tables 14–16 depending on the type of the fracture and the methods used for surgical stabilization.

Table 14. Radiological results in women based on Harnroongroj *et al.* angle in tongue-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 3; 3.6%).

Harnroongroj <i>et al.</i> angle	Result depending on the type of fracture and the method				
	Tongue-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	3	–
3 days after surgery	3	–	–	–	–
3 months after surgery	3	–	–	–	–
6 months after surgery	3	–	–	–	–
12 months after surgery	3	–	–	–	–

Table 15. Radiological results in women based on Harnroongroj *et al.* angle in depression-type fractures of the calcaneus treated with Westhues method with additional stabilization of bone fragments with Kirschner wires (n = 4; 4.8%).

Harnroongroj <i>et al.</i> angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	3	1
3 days after surgery	3	1	–	–	–
3 months after surgery	3	1	–	–	–
6 months after surgery	3	1	–	–	–
12 months after surgery	3	1	–	–	–

Table 16. Radiological results in women based on Harnroongroj *et al.* angle in depression-type fractures of the calcaneus treated with Rapała method (n = 7; 8.5%).

Harnroongroj <i>et al.</i> angle	Result depending on the type of fracture and the method				
	Depression-type fracture				
	Grade				
	Very good	Good	Satisfactory	Poor	Very poor
Time since injury	–	–	–	4	3
3 days after surgery	–	–	5	1	1
3 months after surgery	–	–	5	1	1
6 months after surgery	–	–	5	1	1
12 months after surgery	–	–	5	1	1

Discussion

An articular fracture of the calcaneus is certainly still one of the most difficult problems of modern traumatology generating numerous questions about the advisability and effectiveness of the surgical and non-surgical actions [1, 3, 14, 15]. In this context, some authors conclude that a reasonable and clinically feasible management is the surgical treatment based on minimally invasive percutaneous fixation [7–9, 11, 16, 17]. The authors argue that this method minimizes the area of additional damage both to the soft tissue and the bone, enables efficient fixation of the bone fragments with restoration of the anatomical geometry of the damaged articular surface of the calcaneus, enables the creation of favorable conditions for osteogenesis and thus a rapid return of patients to full health with lower risk of various types of local and systemic complications. Is that a fact? Does minimally invasive percutaneous fixation dominate over others methods used in the surgical treatment of articular fractures of the calcaneus? Does it cause far fewer complications? Does it provide and maintain a convincing stabilization of bone fragments in the early and long-term observation?

Our observations of the surgical treatment of articular calcaneal fractures using minimally invasive percutaneous fixation show that it is in many cases ineffective or susceptible to inflammatory and thromboembolic complications to a similar extent as observed in other fixation methods. It seems that the inflammatory complications observed on the skin at the point of entry of the material to the calcaneus are much more common in minimally invasive percutaneous fixation than internal fixation. Moreover, the fixation remains in this configuration for several weeks, which particularly stimulates inflammatory progression or its destabilization. It is also known that inflammatory complications provoke deep and superficial vein thrombosis, as observed in this study. We also suggest that these complications adversely affect the nature and dynamics of bone healing by promoting secondary movements of bone fragments, as well as a demineralization processes and dystrophic syndrome [2, 12, 18]. Radiographic analysis of the nature and direction of displacement of the bone fragments surgically stabilized in minimally invasive percutaneous fixation based on the Westhues method proves that it is erroneous to use this method in depression-type articular fractures. This type of fixation should be only dedicated to treat tongue-type fractures, which is reflected in the results based both on the measurement of Bohler angle and the varus angle by Harnroongroj *et al.*, in different observation periods [13]. Secondary displacements of bone fragments in the analyzed fractures treated surgically with minimally invasive percutaneous fixation were observed mainly until 3 months after surgery — rarely until 6 months. Long-term observations in this context also suggest that the problem in the surgical treatment of articular fractures of the calcaneus is not bone displacement visualized in the change of Harnroongroj *et al.* angle [13], which is easily repositioned and stabilized. A definitely more difficult problem is the restoration of normal or close to normal Böhler angle and its maintenance in the first three months after the surgery.

Conclusions

1. Results of surgical treatment of articular fractures of the calcaneus using a minimally invasive percutaneous fixation are good and satisfactory in majority of patients, but significantly better in patients with tongue-type fractures.
2. Displacements of bone fragments in articular calcaneal fractures visualized radiographically by the changes of Harnroongroj *et al.* angle do not constitute a serious surgical problem and are easily repositioned and stabilized, as opposed to displacements resulting in changes in the value of the Böhler angle.
3. The most common complications of surgical treatment of articular fractures of the calcaneus using a minimally invasive percutaneous fixation are local inflammatory reactions at the point of entry of fixation material and thromboembolic complications.

Conflict of interest

None declared.

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