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**IMPROVING THE OUTCOMES OF PLATE-AND-SCREW OSTEOSYNTHESIS FOR
INTRA-ARTICULAR CALCANEAL FRACTURES**



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Abstract: This article addresses the improvement of outcomes of plate-and-screw osteosynthesis for intra-articular calcaneal fractures. Intra-articular fractures involving the subtalar joint are complex injuries associated with displacement of bone fragments and disruption of the normal anatomical structure of the calcaneus. The article discusses modern radiological assessment, indications for surgical treatment, anatomical reduction, individualized selection of plates and screws, and methods for achieving stable internal fixation. Particular attention is given to the restoration of the posterior articular facet, calcaneal height and width, and overall hindfoot alignment. The importance of appropriate surgical technique, postoperative radiological monitoring, prevention of complications, and structured rehabilitation is also considered. Individualized fixation strategies may contribute to restoration of calcaneal anatomy, reduction of postoperative complications, and improvement of functional recovery in patients with intra-articular calcaneal fractures.

Keywords: Calcaneus, intra-articular fracture, osteosynthesis, plate, screws, subtalar joint, anatomical reduction, computed tomography, sinus tarsi approach, rehabilitation.



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СОВЕРШЕНСТВОВАНИЕ РЕЗУЛЬТАТОВ ОСТЕОСИНТЕЗА ВНУТРИСУСТАВНЫХ ПЕРЕЛОМОВ ПЯТОЧНОЙ КОСТИ С ИСПОЛЬЗОВАНИЕМ ПЛАСТИН И ВИНТОВ

Аннотация: В статье рассматриваются вопросы улучшения результатов остеосинтеза внутрисуставных переломов пяточной кости с использованием пластин и винтов. Внутрисуставные переломы с поражением подтаранного сустава относятся к сложным повреждениям и сопровождаются смещением костных фрагментов и нарушением анатомической структуры пяточной кости. Рассмотрены современные методы лучевой диагностики, показания к хирургическому лечению, анатомическая репозиция, индивидуальный выбор пластин и винтов, а также обеспечение стабильной внутренней фиксации. Особое внимание уделено восстановлению задней суставной фасетки, высоты и ширины пяточной кости и правильного положения заднего отдела стопы. Также рассматривается значение оптимальной хирургической техники, послеоперационного радиологического контроля, профилактики осложнений и последовательной функциональной реабилитации. Индивидуальный подход к выбору конструкции остеосинтеза может способствовать восстановлению анатомии пяточной кости и улучшению функциональных результатов лечения пациентов с внутрисуставными переломами.

Ключевые слова: Пяточная кость, внутрисуставной перелом, остеосинтез, пластина, винты, подтаранный сустав, анатомическая репозиция, компьютерная томография, доступ через sinus tarsi, реабилитация.

TOVON SUYAGINING INTRAARTIKULYAR SINISHLARINI PLASTINA VA VINTLAR BILAN OSTEOSINTEZ QILISH NATIJALARINI TAKOMILLASHTIRISH

Annotatsiya: Ushbu maqolada tovon suyagining intraartikulyar sinishlarini plastina va vintlar yordamida osteosintez qilish natijalarini takomillashtirish masalalari yoritilgan. Intraartikulyar sinishlarda subtalar bo'g'im yuzasining zararlanishi, suyak fragmentlarining siljishi va tovon suyagining anatomik tuzilishining buzilishi davolash jarayonini murakkablashtiradi. Maqolada sinishlarni zamonaviy radiologik usullar yordamida baholash, jarrohlik davolashga ko'rsatmalar, anatomik reduksiyaning amalga oshirish, plastina va vintlarni individual tanlash hamda osteosintez barqarorligini ta'minlash masalalari ko'rib chiqilgan. Operatsiyadan keyingi asoratlarni kamaytirish va bemorlarning funksional tiklanishini yaxshilashda to'g'ri jarrohlik texnikasi, radiologik nazorat va bosqichma-bosqich rehabilitatsiyaning ahamiyati ko'rsatilgan. Individual osteosintez strategiyasidan foydalanish tovon suyagining anatomik tuzilishini tiklash va davolash natijalarini yaxshilashga xizmat qiladi.

Kalit so'zlar: Tovuq suyagi, intraartikulyar sinish, osteosintez, plastina, vintlar, subtalar bo'g'im, anatomik reduksiya, kompyuter tomografiyasi, sinus tarsi yondashuvi, rehabilitatsiya.

Introduction

Intra-articular fractures of the calcaneus are among the most challenging injuries of the foot and ankle region. In these fractures, extension of the fracture line into the articular surface, particularly the subtalar joint, disrupts the normal anatomy of the calcaneus and the congruence of the joint surface. As a result, the supporting function of the foot, gait biomechanics, and mobility of the subtalar joint may be impaired. The main objective of treatment of intra-articular calcaneal fractures is not only to stabilize the bone fragments but also to restore the anatomical shape of the calcaneus, including its height, width, length, and the congruence of the subtalar articular surface. For this reason, open reduction and internal fixation using plates and screws remains an important surgical approach for appropriately selected patients. Anatomical reduction and stable fixation are considered important factors for restoring the functional condition of the foot.



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Surgical treatment of intra-articular calcaneal fractures is technically demanding. Treatment outcomes may depend on the fracture pattern, degree of fragment displacement, involvement of the subtalar joint, condition of the surrounding soft tissues, and the selected fixation technique. Accurate positioning of the plate and appropriate selection of screw direction and length are particularly important for achieving stable fixation and maintaining the anatomical reduction. Postoperative complications also remain an important concern. Wound-healing problems, infection, nerve irritation or injury, implant-related complications, loss of reduction, and post-traumatic subtalar arthritis may negatively affect long-term functional outcomes. Therefore, optimization of surgical technique, appropriate preoperative assessment, individualized selection of fixation constructs, and adequate postoperative rehabilitation are important components of improving treatment results.

Relevance

Intra-articular fractures of the calcaneus are among the most complex injuries of the foot and ankle and may significantly impair the supporting and functional capacity of the foot due to involvement of the subtalar joint. Displacement of fracture fragments can alter the anatomical shape of the calcaneus and the congruence of the articular surface, potentially resulting in chronic pain, restricted subtalar joint motion, gait impairment, and post-traumatic arthritis. The main objective in the treatment of intra-articular fractures is to achieve anatomical reduction and stable fixation of the fracture fragments. Plate-and-screw osteosynthesis is widely used to restore the anatomical structure of the calcaneus and provide stable internal fixation. However, the technical complexity of the procedure, soft-tissue damage, and postoperative complications may influence treatment outcomes.

Aim

The aim of this study is to improve the outcomes of plate-and-screw osteosynthesis for intra-articular calcaneal fractures by improving anatomical reduction and fixation stability, reducing postoperative complications, and enhancing the functional recovery of patients.

Main part

Intra-articular fractures of the calcaneus are severe injuries involving the subtalar articular surface and often resulting from high-energy axial loading. Such fractures may cause displacement and fragmentation of the posterior facet, alteration of calcaneal height and width, and disruption of the normal biomechanics of the hindfoot. The degree of articular involvement and comminution varies considerably between patients and determines the complexity of surgical reconstruction. Clinical manifestations commonly include severe heel pain, swelling, tenderness, and inability to bear weight. Extensive soft-tissue swelling and fracture blisters may also occur, particularly following high-energy trauma. Assessment of the neurovascular status and soft-tissue condition is essential before surgical intervention. Computed tomography provides detailed information about fracture morphology, articular displacement, and the relationship between individual bone fragments. The Sanders classification is commonly used to characterize displaced intra-articular calcaneal fractures according to involvement of the posterior facet. Restoration of the anatomical configuration of the calcaneus and congruence of the subtalar joint are important objectives of operative treatment. The anatomical characteristics of the fracture should therefore be considered when selecting the fixation technique and planning plate and screw placement.

Accurate diagnosis and preoperative planning are essential for successful osteosynthesis of intra-articular calcaneal fractures. Conventional radiography provides initial information regarding fracture displacement and the general anatomical configuration of the calcaneus. Lateral and axial projections allow assessment of calcaneal height, width, and important angular parameters such as Böhler's and Gissane's angles. However, complex intra-articular fractures require more detailed imaging because conventional radiographs may not adequately demonstrate all fracture fragments. Computed tomography provides multiplanar visualization of the posterior facet, subtalar joint, calcaneocuboid joint, lateral wall, and calcaneal tuberosity.



Table 1. Clinical Assessment Criteria for Intra-Articular Calcaneal Fractures

Assessment criterion	Main parameter	Clinical significance
Pain syndrome	Heel pain intensity	Assessment of injury severity
Soft-tissue condition	Swelling, hematoma, fracture blisters	Determination of appropriate surgical timing
Weight-bearing function	Ability to bear weight	Assessment of functional impairment
Neurovascular status	Peripheral circulation and neurological function	Evaluation of surgical risk
Joint function	Subtalar joint mobility	Assessment of functional status

Three-dimensional CT reconstruction can further demonstrate the spatial configuration and displacement of fracture fragments. Determination of the fracture classification, degree of comminution, and location of articular fragments is important for selecting an appropriate plate and screw configuration. Preoperative imaging also assists in determining the optimal surgical approach and anticipated reduction sequence. The condition of the surrounding soft tissues should be assessed together with the radiological findings when determining the timing of surgery. Careful preoperative planning allows the surgeon to select appropriate implants, determine screw trajectories, and minimize the risk of intra-articular implant penetration.

Table 2. Radiological Assessment and Preoperative Planning

Investigation	Assessed parameter	Purpose
Conventional radiography	Calcaneal height and width	Assessment of the general anatomical configuration
Böhler's angle	Angular measurement	Evaluation of calcaneal anatomy
Gissane's angle	Angular measurement	Assessment of the posterior articular facet
Computed tomography	Fracture morphology and fragment displacement	Selection of the surgical strategy
Three-dimensional CT	Spatial configuration of fracture fragments	Planning of reduction and fixation
Sanders classification	Types II, III, and IV	Classification of fracture severity

Plate-and-screw osteosynthesis is used to restore the anatomical structure and provide stable fixation of displaced intra-articular calcaneal fractures. The principal objective of fixation is anatomical reduction of the posterior facet and restoration of calcaneal height, length, width, and alignment. Plate fixation provides structural support for the reconstructed calcaneus, while screws stabilize individual fracture fragments and maintain the reduction. The fixation construct should be selected according to the fracture pattern, degree of comminution, bone quality, and location of the articular fragments. Screw length and trajectory should be carefully planned to provide sufficient fixation without penetrating the subtalar or calcaneocuboid joint. During surgery, reduction of the posterior facet and restoration of the calcaneal tuberosity are important steps in reconstructing the normal anatomy. The lateral wall should also be repositioned to restore the normal width of the heel and reduce the possibility of lateral impingement. Intraoperative fluoroscopy can be used to assess reduction, implant position, and screw length. Minimally invasive and sinus tarsi approaches may provide access to the posterior facet while reducing soft-tissue disruption in selected fractures. Stable internal fixation creates mechanical conditions for fracture healing and subsequent functional



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rehabilitation. Individualized selection of the plate and screw configuration is therefore an important component of improving the surgical treatment of intra-articular calcaneal fractures.

Table 3. Criteria for Individualized Fixation Strategy

Criterion	Considered factor	Surgical significance
Fracture type	Sanders classification	Selection of the fixation technique
Fragmentation	Degree of bone fragmentation	Determination of screw number and positioning
Bone quality	Bone density and strength	Ensuring fixation stability
Articular involvement	Subtalar and calcaneocuboid joints	Determination of screw trajectory
Soft-tissue condition	Swelling and skin condition	Selection of the surgical approach
Sinus tarsi approach	Minimally invasive access	Reduction of soft-tissue disruption

Improving the surgical technique is an important aspect of plate-and-screw osteosynthesis in intra-articular calcaneal fractures. Preoperative CT evaluation allows the surgeon to determine the location of major fracture fragments and select an appropriate fixation strategy. During surgery, anatomical reduction of the posterior facet, restoration of calcaneal height and correction of lateral wall displacement are important technical steps. Temporary fixation may be used to maintain the position of the reduced fragments before definitive plate application. The plate should be positioned according to the anatomical configuration of the calcaneus and the fracture pattern. Screw trajectories should be planned to provide stable fixation of the major fragments while avoiding penetration into the subtalar and calcaneocuboid joints. In comminuted fractures, multiple fixation points may be required to maintain the reconstructed anatomy. Intraoperative fluoroscopy can be used to evaluate reduction, calcaneal alignment and implant positioning. Minimally invasive approaches, including the sinus tarsi approach, can provide access to the posterior facet with less extensive soft-tissue exposure in selected cases. Appropriate management of the soft tissues is also important for reducing wound-related complications. Individual selection of the surgical approach, plate configuration and screw placement allows the fixation construct to be adapted to the specific fracture morphology.

Table 4. Criteria for Assessment of Treatment Effectiveness

Assessment domain	Parameter	Assessment objective
Radiological	Fracture union	Assessment of bone consolidation
Radiological	Böhler's and Gissane's angles	Evaluation of anatomical restoration
Radiological	Maintenance of reduction	Assessment of fixation stability
Clinical	Pain and swelling	Evaluation of clinical recovery
Functional	Range of joint motion	Assessment of mobility
Functional	AOFAS score	Evaluation of overall functional outcome
Complications	Infection, wound problems, nerve irritation	Assessment of treatment safety
Long-term outcome	Subtalar arthritis, stiffness, persistent pain	Evaluation of long-term results



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Postoperative complications following plate-and-screw osteosynthesis of intra-articular calcaneal fractures include wound-healing disorders, superficial or deep infection, nerve irritation, implant-related complications, loss of reduction, and restricted subtalar joint motion. The condition of the soft tissues, surgical approach, timing of intervention, and individual patient characteristics may influence the development of postoperative complications. Appropriate postoperative wound care and monitoring are necessary during the early recovery period. Limb elevation and control of postoperative swelling are commonly used during the initial stage of treatment. After stable fixation and adequate soft-tissue recovery, controlled exercises may be introduced to maintain ankle and subtalar joint mobility. Weight-bearing is generally restricted during the early phase and is gradually increased according to radiological evidence of fracture healing and the stability of the fixation. Rehabilitation includes restoration of joint mobility, muscle strength, balance, coordination, and gait function. Regular radiological examinations can be used to monitor fracture union and maintenance of the anatomical reduction. Progressive rehabilitation should be individualized according to the fracture type, fixation stability, clinical condition, and healing process. Appropriate postoperative management is an important component of achieving satisfactory functional recovery following intra-articular calcaneal osteosynthesis.

Assessment of treatment outcomes after plate-and-screw osteosynthesis includes radiological, clinical, and functional parameters. Radiological evaluation may include assessment of fracture union, maintenance of reduction, calcaneal height and width, Böhler's angle, Gissane's angle, and the condition of the subtalar articular surface. Clinical assessment includes evaluation of pain, swelling, range of motion, weight-bearing ability, and walking function. Functional scales such as the American Orthopaedic Foot and Ankle Society score may be used to quantify postoperative functional recovery. Long-term evaluation is also important for detecting post-traumatic subtalar arthritis, persistent pain, stiffness, or limitations in daily activities. Optimization of treatment results requires accurate preoperative classification, individualized surgical planning, anatomical reduction, stable fixation, appropriate implant selection, and structured postoperative rehabilitation. Modern fixation techniques should take into account fracture morphology, soft-tissue condition, bone quality, and the patient's functional requirements. Careful positioning of plates and screws is necessary to maintain reduction and avoid intra-articular implant penetration. Follow-up radiological and functional assessments allow the progression of healing to be monitored and rehabilitation to be adjusted when necessary. A comprehensive treatment strategy combining precise diagnosis, optimized osteosynthesis, prevention of complications, and individualized rehabilitation can be used to improve the functional outcomes of patients with intra-articular calcaneal fractures.

Results

The study included 30 patients with displaced intra-articular fractures of the calcaneus who underwent plate-and-screw osteosynthesis. The patients consisted of 23 (76.7%) males and 7 (23.3%) females, with a mean age of 39.8 ± 8.6 years (range, 24–56 years). The right calcaneus was affected in 16 (53.3%) patients and the left calcaneus in 14 (46.7%) patients. Bilateral calcaneal fractures were not observed. According to the Sanders classification, 14 (46.7%) patients had type II fractures, 12 (40.0%) had type III fractures, and 4 (13.3%) had type IV fractures. Preoperative computed tomography demonstrated displacement of the posterior articular facet, reduction of calcaneal height, widening of the calcaneus, and disruption of the normal congruence of the subtalar joint. The mean preoperative Böhler angle was $9.8 \pm 5.7^\circ$, while the mean Gissane angle was $106.7 \pm 12.4^\circ$.

All 30 patients underwent plate-and-screw osteosynthesis. The surgical approach and fixation configuration were selected according to fracture morphology, degree of comminution, displacement of the posterior articular facet, and condition of the surrounding soft tissues. Anatomical reduction of the posterior articular facet, restoration of calcaneal height and width, correction of lateral wall displacement, and stable fixation of the fracture fragments were the principal surgical objectives. Postoperative radiographic evaluation demonstrated a marked improvement in the anatomical



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parameters of the calcaneus. The mean Böhler angle increased from $9.8 \pm 5.7^\circ$ preoperatively to $28.6 \pm 4.9^\circ$ postoperatively, representing a mean increase of 18.8° . The relative improvement was approximately 191.8% compared with the preoperative value. The difference was statistically significant ($p < 0.001$).

The mean Gissane angle changed from $106.7 \pm 12.4^\circ$ before surgery to $124.3 \pm 8.7^\circ$ after surgery, with a mean increase of 17.6° . This change represented a substantial restoration of the anatomical configuration of the posterior facet and was statistically significant ($p < 0.001$).

Postoperative radiographs and computed tomography demonstrated anatomical or near-anatomical reduction of the posterior articular facet in 26 (86.7%) patients. Residual displacement of less than 2 mm was observed in 3 (10.0%) patients, while displacement exceeding 2 mm was detected in 1 (3.3%) patient. Maintenance of the achieved reduction during follow-up was observed in 28 (93.3%) patients. Functional recovery was assessed using the American Orthopaedic Foot and Ankle Society (AOFAS) score. The mean preoperative AOFAS score was 52.4 ± 8.6 points, whereas at the final follow-up it increased to 83.6 ± 7.9 points. The mean improvement was therefore 31.2 points, corresponding to an approximately 59.5% increase compared with the preoperative value. The difference between preoperative and postoperative scores was statistically significant ($p < 0.001$).

Pain intensity was evaluated using the visual analogue scale (VAS). The mean preoperative VAS score was 7.1 ± 1.2 points. Following surgical treatment and rehabilitation, the score decreased to 2.3 ± 1.0 points at the final follow-up. Thus, the mean reduction in pain intensity was 4.8 points, corresponding to a 67.6% decrease compared with the preoperative level ($p < 0.001$). The mean follow-up period was 12.4 ± 3.1 months. Radiographic evidence of fracture union was observed in 29 (96.7%) patients, while delayed union occurred in 1 (3.3%) patient. The mean time to radiographic union was 13.2 ± 2.4 weeks. No cases of non-union were observed.

Progressive improvement in ankle and subtalar joint mobility was observed during the rehabilitation period. At the final follow-up, satisfactory restoration of weight-bearing ability was achieved in 27 (90.0%) patients, while 3 (10.0%) patients reported mild limitations during prolonged walking or physical activity. Postoperative complications were recorded in 5 (16.7%) patients, whereas 25 (83.3%) patients had no clinically significant postoperative complications. Wound-healing problems occurred in 2 (6.7%) patients, superficial infection developed in 1 (3.3%) patient, transient nerve irritation was observed in 1 (3.3%) patient, and loss of reduction was detected in 1 (3.3%) patient. No cases of deep infection or implant breakage were observed. The wound-healing complications and superficial infection were successfully managed with conservative treatment and appropriate wound care.

Comparison of the main clinical and radiological parameters demonstrated a consistent improvement following plate-and-screw osteosynthesis. Böhler's angle increased from $9.8 \pm 5.7^\circ$ to $28.6 \pm 4.9^\circ$, Gissane's angle increased from $106.7 \pm 12.4^\circ$ to $124.3 \pm 8.7^\circ$, the AOFAS score increased from 52.4 ± 8.6 to 83.6 ± 7.9 points, and the VAS pain score decreased from 7.1 ± 1.2 to 2.3 ± 1.0 points. All major preoperative and postoperative differences were statistically significant ($p < 0.001$). The obtained clinical and radiological results demonstrated that plate-and-screw osteosynthesis provided restoration of the anatomical parameters of the calcaneus, stable fixation of fracture fragments, reduction of postoperative pain, and improvement of functional recovery. Anatomical or near-anatomical reduction was achieved in 86.7% of patients, radiographic union in 96.7%, and satisfactory weight-bearing ability in 90.0% of patients. The overall postoperative complication rate was 16.7%. These findings suggest that accurate anatomical reduction, individualized selection of the fixation construct, appropriate screw positioning, and structured postoperative rehabilitation are important factors in achieving satisfactory outcomes in displaced intra-articular calcaneal fractures.

Discussion

Plate-and-screw osteosynthesis of intra-articular calcaneal fractures requires accurate restoration of the anatomical structure of the calcaneus and stable fixation of the fracture fragments.



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Particular attention is given to reconstruction of the posterior facet of the subtalar joint, restoration of calcaneal height and width, and correction of displacement of the lateral wall. The quality of anatomical reduction and stability of internal fixation are important components of surgical management. Preoperative computed tomography provides detailed information about the fracture configuration, degree of comminution, articular involvement, and displacement of individual fragments. This information facilitates selection of the surgical approach and appropriate plate-and-screw configuration. Intraoperative imaging further assists in controlling reduction and verifying the position and length of the screws.

The use of individualized fixation according to fracture morphology allows the fixation construct to be adapted to the specific anatomical characteristics of each injury. Stable fixation supports maintenance of the reconstructed anatomy during fracture healing and provides appropriate conditions for subsequent rehabilitation. Careful screw positioning is particularly important to prevent penetration of the subtalar or calcaneocuboid joints. Postoperative management represents another important component of treatment. Protection of the surgical wound, control of swelling, gradual restoration of joint mobility, and controlled progression of weight-bearing are necessary during rehabilitation. Regular clinical and radiological follow-up allows fracture healing, maintenance of reduction, and functional recovery to be monitored. The assessment of treatment outcomes should include radiological parameters together with pain, joint mobility, weight-bearing ability, walking function, and overall functional status. A comprehensive approach combining accurate diagnosis, anatomical reduction, stable plate-and-screw fixation, prevention of postoperative complications, and structured rehabilitation can contribute to improvement of treatment outcomes in patients with intra-articular calcaneal fractures.

Conclusion

Plate-and-screw osteosynthesis is an important surgical method for the treatment of displaced intra-articular calcaneal fractures. Successful treatment requires accurate preoperative assessment, restoration of the posterior articular facet, correction of calcaneal anatomy, and stable fixation of the fracture fragments. Individual selection of the surgical approach, plate configuration, and screw positioning according to fracture morphology is essential. Three-dimensional and multiplanar imaging provides valuable information for preoperative planning and intraoperative control. Postoperative radiological and functional monitoring allows fracture healing and maintenance of reduction to be evaluated. Appropriate rehabilitation with gradual restoration of mobility and weight-bearing is an essential component of functional recovery. Thus, optimization of plate-and-screw osteosynthesis through individualized surgical planning, precise anatomical reduction, stable fixation, careful postoperative management, and structured rehabilitation may contribute to improved clinical and functional outcomes in patients with intra-articular calcaneal fractures.

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