Clinical case
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Ankle joint replacement for necrosis of the talus, crusarthrosis, equinovarus and adducted foot

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Abstract

Introduction Surgical treatment of patients with avascular osteonecrosis of the talus and post-traumatic hindfoot deformity is associated with high morbidity, difficulty of early disease detection, the discrepancy between patient expectations and orthopaedic requirements for surgical outcomes due to traditional methods. The use of customized ankle joint replacement may be a potential solution to this problem.

The objective was to evaluate the results of treatment of a patient with avascular osteonecrosis of the talus, crusarthrosis and hindfoot deformity using an original replacement method for the ankle joint and the talus.

Material and methods A 30-year-old patient with post-traumatic avascular osteonecrosis of the talus, crusarthrosis, equinovarus and adducted foot underwent replacement of the ankle joint and talus using the method developed by the authors. Radiographic and tomographic methods were used for diagnosis. The VAS scale, AOFAS, FFI, EFAS questionnaires and pedobarography were used to assess clinical and functional results.

Results The results of treatment evaluated at 12 months showed maintained foot deformity correction, stability of a tailored construct with no signs of loosening and osteolysis. The clinical and functional result showed a 81/2 VAS decrease in pain, functional status improved by 4.3 times with functional foot index (FFI) improved by 2.2 times according to the AOFAS scale at 12 months.

Discussion Orthopaedic surgeons are conducting research aimed at preserving ankle motion in the treatment of avascular osteonecrosis of the talus. A serious problem is associated with concomitant deformities of the hindfoot and available implants fail to solve this problem.

Conclusion The surgical method offered for the patient provided good clinical and functional results with the hindfoot deformity corrected within one stage reducing the treatment time.

Keywords: avascular necrosis, aseptic necrosis, osteonecrosis, arthrodesis, arthroplasty, ankle joint, talus, custom-made talus prosthesis, ankle joint replacement

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INTRODUCTION

Avascular osteonecrosis of the talus (AOT) is a severely disabling disease. Osteonecrosis of the talus (OT) of different etiology is difficult to diagnose in the early stages of the disease and patients seek medical attention in advanced stages developing a severe deformity of the hindfoot and ankle joint [1]. Surgical treatment of the condition is generally accepted [2]. Massive loss of the talus bone, post-traumatic changes in the ankle joint result in a complex fixed hindfoot deformity preventing primary and revision ankle replacement to maintain motion in the joints of the hindfoot. In retrospect, the main treatment method was considered to be Astragalectomy was historically recommended for avascular necrosis of the talus of different origins in cases of the most severe lesions of the talus including fragmentation, resorption and inability to preserve the joints surrounding the talus [3]. The functional outcomes of the procedure fail to comply with the current level of patient expectations and orthopaedic requirements for the results of surgical treatment [4].

Surgical treatments of OT of different etiologies and the consequences include tibiotalocalcaneal arthrodesis, panarthrodesis of the foot with massive bone auto- and alloplasty of defects added by reconstructive interventions as indicated [2]. With all the advantages the surgical treatment can be associated with significant disadvantages including high morbidity, irreversible loss of movement in the functionally important joints of the hindfoot, high risk of nonunion, high incidence of residual deformities and long periods of limb immobilization [5–8]. Methods aimed at preserving biomechanics in the joints of the hindfoot are essential for the total AOT [9]. Additive technologies, interaction between surgeons and engineers and the use of safe materials and alloys are practical for developing original designs and new surgical treatments using modern technologies [10].

In addition to AOT, concomitant deformity of the hindfoot and ankle joint is essential for determining indications for ankle replacement. This can be an absolute contraindication to primary ankle replacement using existing designs [11]. Some authors support multi-stage surgical treatment to include deformity correction, osteotomy of adjacent bones, arthrodesis of subtalar, talonavicular, calcaneocuboid joints and bone auto- and allograft of defects at the first stage [12] creating conditions for ankle joint replacement at the second stage of surgical treatment with preserved talus structure. Otherwise, there is a high risk of instability of the endoprosthetic components and infection. A logical question arises: how to overcome the shortcomings and improve the results of treatment of patients with post-traumatic equino-varo-adduction deformity of the foot and ankle joint with osteonecrosis of the talus of different etiologies, with post-traumatic osteoarthritis of the ankle joint maintaining movement in the joints of the hindfoot? In our opinion, a potential solution may include a custom-made implant for the talus with use of additive technologies, a surgical procedure performed with the method we have developed for replacement of the ankle, talonavicular, subtalar joints using an original implant of the talus, reproducing the lost anatomy and spatial orientation of the hindfoot, ankle joint, adapting its configuration with the articulating surface of the fixed liner and the tibial component of the ankle implant [13].

The objective was to evaluate the results of treatment of a patient with avascular osteonecrosis of the talus, crusarthrosis and hindfoot deformity using an original replacement method for the ankle joint and the talus.

MATERIAL AND METHODS

Data for the study included findings of a 30-year-old patient with post-traumatic avascular necrosis of the talus that resulted in post-traumatic osteoarthritis of the ankle joint and adduction equinovarus deformity of the foot and ankle joint. An original method of ankle joint replacement was employed for surgical treatment using tailored-made implants obtained with 3D reconstruction and modeling of the intact talus and contralateral ankle joint. Clinical effectiveness included hindfoot deformity correction, stable implant and absent signs of osteolysis around the components seen at the follow-up examination. Outcome measures included conventional radiography, multislice computed tomography, static and dynamic pedobarography, questionnaires and scales for assessment of the foot and ankle function: American Orthopedic Foot & Ankle Society (AOFAS) score, European Foot and Ankle Society (EFAS) score, Foot Function Index (FFI) and visual analog scale (VAS) pain. The group of authors obtained consent from the patient to participate in the study and publish the results without personal identification.

RESULTS

In 2022, a female patient Sh. born in 1992, was admitted to the 4th trauma and orthopaedic department (department of foot and ankle surgery) of the City Clinical Hospital named after S.S. Yudin (Moscow). She presented with pain, severe hindfoot deformity on the right side, persistently limited motion in the ankle, subtalar, talonavicular joints, swollen soft tissues of the right ankle joint. The patient reported home accident in 2014, she fell from her own height on her right foot and sustained an open fracture of the talar neck on the right foot with subtalar, talonavicular and ankle dislocation, Hawkins Type IV type IV [14] (Fig. 1, a, b). She was delivered to the trauma department of the hospital as an emergency. Surgical treatment performed for her included open reduction and screw fixation of the right talus (Fig. 1, c, d). The postoperative period was uneventful, the bone healed by primary intention, and the lower limb was immobilized with a plaster cast for three months. With bone consolidation, plaster immobilization was suspended and the patient was treated conservatively. In 2016, the screws were removed at the place of residence with technical difficulties (fracture of screws); the components were partially removed due to the high probability of traumatic injury to the talus. Between 2016 and 2022, the pain progressed, hindfoot deformity and persistently limited range of motion developed with swollen soft tissues in the ankle. The right foot appeared adducted and supinated with the apex of the deformity at the the talonavicular joint. She developed fixed equinus alignment at the level of the ankle joint and varus deformity of the calcaneus at the level of the subtalar joint accompanied by persistent painful contracture.

The patient could take no more than 5,000 steps per day. Conservative treatment failed and a comprehensive physical and radiological examination was performed. Anteroposterior and lateral views of both feet and ankle joints (Fig. 1, e, f) showed collapsed talus, post-traumatic varus deformity of the talus, foreign bodies with screw debris in the body of the right talus, post-traumatic right-sided grade III crusarthrosis.

A multislice computed tomography of the right ankle joint (Fig. 2, a, b) demonstrated the outcome of post-traumatic aseptic necrosis of the talus and deformed right ankle. The articular surfaces appeared to be indistinct, uneven, and subchondral osteosclerosis of the articular surfaces with cyst-like restructuring noted. The joint space was filiformly narrowed. A 3D reconstruction of the ankle with 3D modeling of the right foot showed varus deformity of the talus, supinated and adducted foot, collapsed talus and foreign bodies with screw debris in the body of the talus). Radiographs and MSCT of the ankle indicated signs of post-traumatic avascular necrosis of the talus and its complications in the form of collapsed talus, multiple cysts in the tibia, talus, etc. Based on clinical findings and data from instrumental examination methods, a diagnosis was made: The patient was diagnosed with post-traumatic avascular necrosis of the talus, collapsed trochlea of the talus of the right foot, grade III deforming osteoarthritis of the ankle joint, fixed adduction equinovarus deformity of the right foot and adducted forefoot. Surgical treatment using our patented method (Patent 2800562 of the Russian Federation "Method of ankle joint replacement for post-traumatic equinovarosis adduction deformation of the foot and ankle joint with necrosis of the talus of different etiologies with post-traumatic osteoarthritis of the ankle joint") was offered for the patient to preserve the biomechanics of motion in the ankle, subtalar, talonavicular joints, correct hindfoot deformity and reduce postoperative rehabilitation [13].

Fig. 1 Anteroposterior and lateral views of the right ankle joint showing (a, b) a fracture of the talar neck with dislocation in the subtalar, talonavicular and ankle joints (2014); (c, d) fracture-dislocation of the talus reduced, internal fixation with screws performed (2014); (e, f) outcome of AOT, collapsed talus, post-traumatic varus deformity of the hindfoot, screw debris in the body of the right talus, post-traumatic right-sided grade III crusarthrosis (2022)

The operation using the method of ankle joint replacement offered consisted of the following steps:

Preoperative planning MSCT of the contralateral normal talus and its mirror reconstruction were performed. A tailored-made talus implant was created considering such parameters as the shape, size, and volume of the intact contralateral talus, mirrored and adapted to the implantation side.

On the block of the tailored-made talus implant, a dovetail-type notch was formed, matching to the polyethylene insert of the ankle joint implant in shape and size. Measurements, relationships and spatial orientation of the talus in the subtalar, talonavicular, and ankle joints were assessed using a virtual model, evaluating the talo-metatarsal angle [15], axis of the talus [16], talocalcaneal angle (Keith angle) [17].

Surgical procedure A tourniquet was applied, Achilles lengthening performed, access made along the anterior surface of the ankle joint between the tendons of the long extensor of the 1st toe and the tibialis anterior muscle, the skin and subcutaneous fat were dissected layer by layer to the bone, protecting the neurovascular bundle, and subperiosteal dissection performed in the lateral and medial directions to expose tibial pylon, talar neck and head, ankle joint, the synovial membrane of the ankle joint was excised, the remains of the fragmented talus were resected and removed with astragalectomy performed (Fig. 2, c, d). A tailored-made implant of the talus adapted to the polyethylene insert and the tibial component of the ankle implant in shape and size was placed in the bed, the tibial component of the ankle joint was installed, an impactor fixed into the tibial component to press the polyethylene insert and the polyethylene insert was implanted (Fig. 2, e, f).

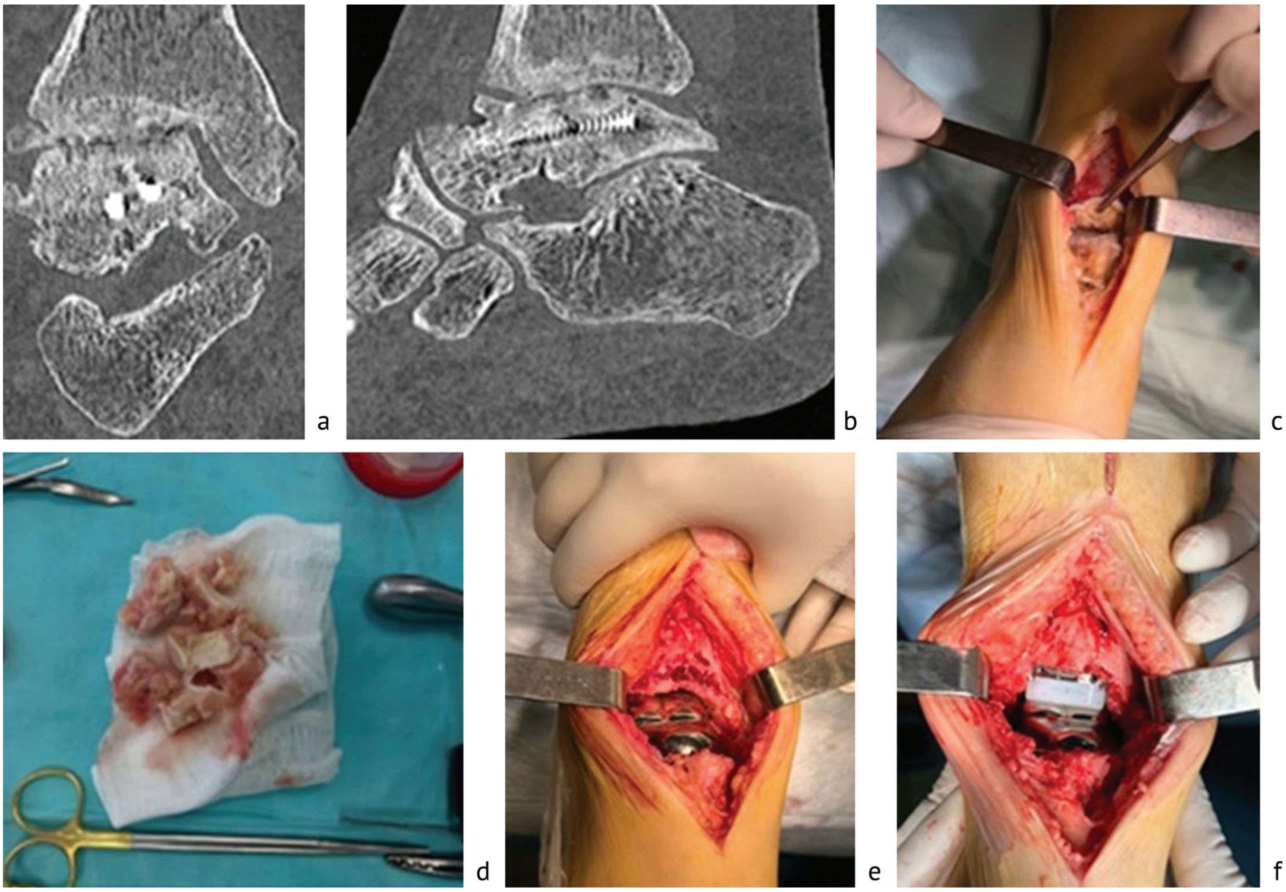

Fig. 2 Coronal and sagittal MSCT scans of the ankle joint showing (a, b) outcome of post-traumatic AOT, collapsed talus, multiple cysts of the tibia and talus. Intraoperative photos demostrating (c) surgical approach to the ankle joint; (d) fragmented, necrotic talus; (e) implanted tailored-made implant of the talus; (f) tailored-made implant of the ankle joint and talus assembled with a tibial component and a polyethylene liner

Hemostasis was performed after removal of the tourniquet, the wound sutured in layers, an aseptic bandage applied and immobilization produced with a deep posterior plaster splint. The drainage was removed the next day.

Postoperative treatment Dressings were changed, subsequent immobilization produced with a removable rigid orthosis and medication administered. The patient was recommended to walk with crutches without weight-bearing on the operated lower limb for 4 weeks. Immobilization and anticoagulant therapy were suspended at 4 weeks as planned. The patient started to bear weight on the operated leg using crutches and gradually abandoned them over a month with a follow-up examination. Massage, physiotherapy, kinesiotherapy and physical therapy were administered. A dynamic control examination using radiography and MSCT of the operated ankle and foot was produced at 12 months (Fig. 3, a–h).

The concomitant adduction equinovarus deformity of the foot was corrected due to exact fit of the talus block and the polyethylene insert fixed into the tibial component of the ankle implant to ensure motion in the ankle, subtalar, and talonavicular joints. The patient was asked to fill in questionnaires preoperatively and at 12 months to assess pain using the visual analog pain scale (VAS) [18], functional parameters using AOFAS [19] and the functional foot index (FFI) [20], EFAS score [21] and the results of static and dynamic pedobarography. The findings demonstrated a significant improvement with decrease in pain, improved functionality (Table 1) and biomechanics of the foot, a decrease in the overload of the hindfoot and more uniform distribution of axial load between the forefoot, middle and hindfoot (Fig. 3 f, g). At the last follow-up visit, the patient was able to produce more than 9000 steps per day.

Fig. 3 Anteroposterior and lateral views of the right ankle joint showing (a, b) AP view of the right foot with imitated support (c) at 12 months. Coronal, sagittal, axial MSCT scans of the right ankle and foot (c, d, e). Precise relationship of the custom-made talus implant in the subtalar, talonavicular joints with the congruence and alignment provided between the implant, polyethylene liner and tibial component of the ankle replacement. Results of pedobarography of the right foot: prior to tailored-made implantation of the ankle joint and talus (f), at 12-month follow-up (g). There is a decrease in the overload of the hindfoot with weight-bearing evenly distributed between the anterior, middle and posterior portions of the foot

Table 1

Assessment of the clinical and functional condition of the foot using questionnaires

Scale/ Questionnaire	Pre-op	12-month follow-up
VAS	85	10
AOFAS	36	80
FFI	100	23
EFAS	12.5	31.5

Note: VAS, Visual Analogue Scale; AOFAS, American Orthopedic Foot & Ankle Society; FFI, Foot Function Index; EFAS, European Foot and Ankle Society

DISCUSSION

Severely displaced fractures and fracture-dislocations of the talus (Hawkins type IV) should be reduced and fixed with or without external fixation shortly after injury to arrange for the next stage of surgical treatment including open reduction and internal fixation. Surgical treatment suggests special care for removal of the periosteum with the resection needed only for anatomical reduction. Rigid, stable internal fixation should be provided with cortical lag screws to be placed at or below the midpoint of the talar head and locking plates can be added. The timing of the definitive procedure for displaced fractures is not associated with the risk of osteonecrosis; it is important to preserve the talus length and restore the anatomy [22]. However, the risk of post-traumatic AOT can range from 50 % to 100 % at a long term even with excellent anatomical open reduction and internal fixation of bone fragments [23–25]. The extent of preoperative bone displacement can be the best predictor for post-traumatic avascular necrosis. Avascular necrosis is associated with cysts and scarry degeneration in the body of the talus, collapse and fragmentation resulting in severe post-traumatic deformities of the hindfoot and ankle joint, persistent contractures and severe pain. Post-traumatic AOT, concomitant severe deformities of the hindfoot and ankle joint can prevent primary ankle joint replacement using commercially available implants with low regenerative potential for bone fusion and a high risk of early instability. Development of new surgical methods can be a promising and relevant solution aimed at preserving biomechanics in the joints of the hindfoot in patients with avascular osteonecrosis, total bone involvement and concomitant deformities of the hindfoot and ankle joint. Treatment of acute cases causes great difficulties for trauma surgeons and outcomes of the disease are compromising for orthopaedic surgeons. Long periods of immobilization, nonunion, shortening of the lower limb, severe deformities can lead to disability of patients with the majority being young and active individuals. Our experience and foreign publications on talus arthroplasty demonstrate good long-term results from the use of the complex constructs [26]. The authors report successful results of talus replacement in the treatment of patients with traumatic extrusion of the talus in pediatric populations [27] and in adult patients [28].

A natural proposal arises for a paradigm shift in the approach to treating patients with traumatic loss of the talus, fracture-dislocations accompanied by massive bone loss. In our opinion, a potential and promising solution may include an individual approach to the trauma and orthopaedic patients, patient-specific talus replacement using additive technologies, a combination of the tibial pylon with implantation, the tibial component of the ankle implant and polyethylene liner as indicated. There are discussions regarding materials of the friction pair of a tailored-made implant, the relationship to the capsular-ligamentous apparatus of the ankle joint, one-/two-stage surgical treatment (stage 1:

correction of hindfoot deformity, stage 2: ankle joint replacement), cemented or cementless fixation of a tibial component, fixation of the talus implant in the subtalar joint. Two types of materials can be used to create a tailored-made talus implant: TI64ELI alloy and zirconium ceramics. The use of implants made of steel, aluminum oxide ceramics, titanium alloys are reported [26, 29]. The capsular-ligamentous apparatus of the ankle joint was repaired according to indications in two cases: (1) distal tibiofibular syndesmosis, (2) anterior talofibular ligament). The talus implant was not fixed to the subtalar and talonavicular joints in all our clinical cases. Concomitant deformities of the hindfoot are associated with technical difficulties in creating a custom-madetalus implant. The usual mirrored model of an intact talus does not correspond to the implantation site in shape and size with post-traumatic changes, that would result in failure of performing total talus arthroplastyand ankle joint. If the implantation is produced in the case, then the persistent post-traumatic deformity and pain would raise a question about a long-term survival.

The technical result of the invention we offered and introduced into practice includes correction of the talus deformity, pain relief and preserved range of motion in the ankle, subtalar and talonavicular joints through the use of a custom-made talus implant in combination with a tibial component and a polyethylene insert of the ankle implant fixed in it [13]. The specific feature of the implant was that the shape, size, volume of the intact talus were measured, adapted the bone to the measurement parameters and spatial orientation in the subtalar, talonavicular and ankle joints, the site of implantation, evaluated such parameters as the talo-metatarsal angle, axis of the talus, talocalcaneal angle (Keith's angle). The risks were properly explained and discussed with the patient. With ankle arthrodesis presented to her as an alternative procedure, the patient selected for total ankle arthroplasty using our method. Our team and the patient were satisfied with the outcome at one year. Each case of AOT requires an individual differentiated approach to treatment. Due consideration and care must be taken treating patients with associated hindfoot deformities, with careful preoperative planning and appropriate preparation of implantation considering all factors that may affect implant survival. We performed 9 custom-made implantations between 2019 and 2023 using the method offered.

CONCLUSION

The patient treated with the surgical method devised showed good clinical and functional results with the hindfoot deformity corrected in one stage reducing the treatment time. Custom-made talus implantation facilitated concomitant hindfoot and ankle deformity correction with the use of additive technologies, preserving biomechanics in the hindfoot joints and providing good short- and long-term results.

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