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Arthrodesis of the Ankle

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SUMMARY

About 90 % of all cases of painful posttraumatic ankle arthritis can be very successfully treated with a minor invasive ankle arthrodesis technique by using a small anterior approach and a fixation with four 6. 5 mm screws of which the posteromedial and transfibular one are inserted percutaneously. The results with this standardized procedure have been reported previously as excellent and good in a mid-term run of 6 years (34). This technique leads to a high union rate of 99% (92 of 93) with rapid bone healing within 8 ± 2 weeks, it causes a low minor complication rate of 8 % and enables a significant increase of the AOFAS ankle/hindfoot score (17) from 36 preoperatively to 85 postoperatively as well as a midtarsal movement of 24° ± 16°. In some cases of ankle arthritis due to chronic syndesmotic instability a 5th screw is additionally used to compress the reamed espace claire for regaining a stable ankle fork. A 5th screw is used also in case of necessary shortening of the fibula or in cases of idiopathic ankle arthritis with gross varus deformity when a transfibular approach becomes necessary instead of the anterior approach. About 10% of ankle arthrodesis need different procedures like in cases of malunited ankle or pilon fractures with low grade infection, larger bony defects due to resection of necrotic bone, due to primary bone loss in open fractures or due to secondary bone loss in failed ankle replacement cases. They need usually a two stage procedure with primary debridement and temporary joint transfixation and secondary anterior double plate fixation with autogenous bone grafting. In case of critical anterior soft tissues a posterolateral approach with a bladeplate-fixation is performed. In the very rare cases of severe ankle infection a three stage procedure is recommended with a radical necrectomy of infected soft tissues or dead bone and/or combined with taking biopsies, filling the defects with Gentamycin-PMMA- beads and stabilizing the reamed joint with a threaded compression Charnley fixator in the first stage. A re-debridement in the second stage might need additionally a permanent lavage with sensitive antibiotics according to the probes and in the third stage a third debridement with finally autogeneous bonegrafting is done.

Key words: ankle arthrodesis, anterior, posterolateral, transfibular ankle approach, 4- to 5-screw fixation technique, double plate fixation, autogeneous bonegrafting, Charnley compression fixator.

INTRODUCTION

The term “arthrodesis” was first used in 1878 by the Austrian surgeon Eduard Albert (2), when he performed a surgical procedure for fusion of both knees and both ankles in a 14-year-old child suffering from a severe palsy of both lower extremities. But it lasted up to the 1930ies before several authors recognized ankle fusion as a salvage procedure for a painful ankle joint due to a malunited ankle fracture (14, 25). In 1951 Charnley (9) introduced as first the compression arthrodesis of the ankle using an external fixation device avoiding by this procedure bone grafting. This operative technique with threaded bars is still today used in case of a severely infected ankle joint as the method of choice. About 30 years later Wagner and Pock (28) introduced 1982 the 3-screw fixation technique for ankle arthrodesis. Since 1993 percutaneous screw fixation as a new technique became popular when Ogilvie et al. (21) used arthroscopy for the joint debridement. Nowadays experience exists in more than 40 different operative procedures with different approaches and implants like nailing, plating, fixing with external fixators including the Ilizarov device or fusing the joint with screws. Most authors agree that internal fixation is superior to external.

For educational reason this paper is written to summarize a personal 40-year surgical experience related to the treatment of ankle arthritis. Therefore a simple systematic approach for decision making is reported about when and how to fuse with 5 main methods an ankle joint in special situations stressing out that still today ankle arthrodesis is the gold standard compared to ankle replacement.

MATERIAL AND METHODS

For this decision making defined diagnosic steps, clear and early decided indications for the best choice of the operative arthrodesis technique are necessary to solve successfully the problems of patients with a painful arthritic ankle joint. At least the surgeon must be convinced that no other joint preserving operation could give relief of pain to the patient.

Fig. 1. Clinical view from behind to judge hindfoot varus or valgus. Only 8° of varus makes a reversed "beek-a-boo-heel" (seing the metatarsal head).

Fig. 2. Standardized weightbearing X-rays of both ankles. a – AP view with 20° of internal rotation of the both feet as a "mortise view" for judging arthritis of the ankle joint central, medial and lateral (red arrows). In this patient arthritis is severely in all three compartments of the right ankle but only medially in the left ankle, judging as well the subtalar joint (yellow arrows) which is normal in the right foot, but arthritic in the left one. For preoperative planning the LDTA (Lateral Distal Tbial Angle) should be measured (1) which is rightsided with 89° normal (22), but pathological measuring 94° leftsided causing hindfoot varus and arthritis of the medial ankle joint (red arrow). The "espace claire" (2) in this patient is widened in the right ankle (normal: 2 to 5 mm) due to chronic syndesmotic instability causing severe arthritis according Bargon type 3 (3). b – Standardized lateral weightbearing view of foot and ankle bothsides showing significantly the anterior shift (11 mm) of the whole foot rightsided in relation to the tibial axis and the center of the talus corpus which are congruent leftsided. Notice that subtalar arthritis is as well seen in the lateral view leftsided but not rightsided (yellow arrow). c – Standardized weightbearing hindfoot alignement view according to Saltzman (23) which shows precisely how much of hindfoot varus is given

Diagnostics

The preoperative **clinical** investigations include a precise anamnesis related to previous history, the amount and exact localisation of the pain, the clinical measurements of equinus, varus or valgus deformity (Fig. 1), measurements of mobilty of the ankle, subtalar and midtarsal joints. Furthermore the preoperative proofs should include functioning of the extrinsic foot muscles, pulses and sensitivity to select pure arthritic ankles from Charcot-Marie-Tooth-ankles, arteriosclerotic or diabetic Charcot feet and ankles.

Radiological diagnostics include weihgtbearing X-rays (Fig. 2a–c) of both ankles AP with 20° of internal rotation of the feet, exact lateral views of the whole foot with ankle, dorso-plantar views and hindfoot views according to Saltzmann (23). They are necessary to judge the amount of deformity of the ankle and hindfoot and the stage of arhritis according to Bargon (3) in the ankle, subtalar and talonavicular joints. The simple Broden's view (6) with 20° tilting of the X-ray beam (Fig. 3) is very helpful to confirm or exclude accompanying subtalar arthitis. CT-scanning or MRI are only requested in special cases of supposed infection and/or bone-necrosis. Sometimes a SPECT-CT, a simple Te-Szintigram or local lidocain infiltrations of the ankle and/or subtalar joint are necessary to differentiate pain which is coming from the ankle joint, subtalar joint or both joints.

Indications

> *Painful posttraumatic arthritis*
> *Talar collapse*
> *Degenerative joint disease*
> *Rheumatoid arthritis*
> *Joint defects/infections*
> *Tumors with joint invasion*
> *Failed ankle replacement*

Relative contraindications are given if the joint problem can be solved by ligament or cartilage repair, by special osteotomies or very individually indicated by joint replacement.

Absolute contraindications are rare like vascular diseases or local soft tissue problems requiring lower leg amputation or allowing not any operation due to the general health conditions of the patient.

Fig. 3. If no CT scan is available the Broden's view with 20° X-ray beam (same patient as in Fig. 2) shows precisely arthritis in the ankle joint bothsided (red arrows) and especially in the subtalar joint only leftsided (yellow arrows)

Note: important is to indicate ankle arthrodesis early before adjacent joints become stiff and arthritic!

OPERATIVE TECHNIQUES

The operative technique is depending on the amount of deformity, of bony necrosis, defect or bone stock as well as on the soft tissue conditions like unstable scars, infection , skin defects or need of additional procedures. In about 90% of all cases ankle arthrodesis with screws is possible and recommended, for all including the remaining 10% of cases 5 different operative techniques are presented here.

1a. Anterior 4-screw-technique

This standardized own minimal-invasive ankle arthrodesis introduced in 1988 (32) is defined by a short anterior approach with reaming the joint and stabilizing it with 2 screws via the open approach and with another two screws percutaneously (Fig. 4). It minimizes postoperative malalignements because wether any resection with a saw nor osteotomy of the medial or lateral malleolus is performed keeping therefore the anatomic shape of ankle fork during operation. It gives high primary stability allowing functional aftertreatment in a special boot with flexible sole (Vario Stabil Boot).

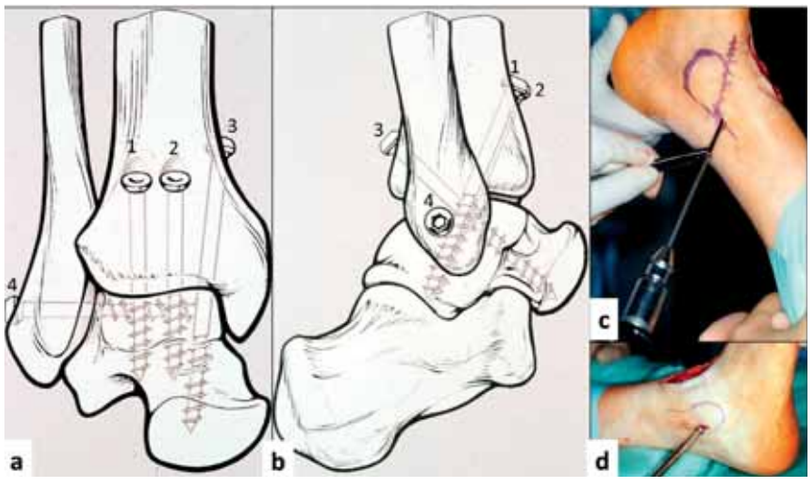

Fig. 4. Standardized fixation with four 6.5 mm cancellous screws. Screw 1 and 2 with a 16 mm thread are inserted from the short anterior open approach, screw 3 and 4 with a 32 mm thread are inserted by stab incisions.

For this standardized operation a supine positioning of the patient is needed, a tourniquet for about 60 minutes and a relative short anterior midline approach of 6 to 8 cm of length (Fig. 5a). The proximal extensor retinaculum is incised in a zick-zack manner for better readaptation at the end of the operation (Fig. 5b), dissecting then between the anterior tibialis tendon and the extensor halluces longus tendon (Fig. 5c), holding the untouched neurovascular bundle with a round hook laterally. After resection of the joint capsule the rests of cartilage (Fig. 6a, b) are taken away with sharp spoons, curettes, straight and bowed osteotomes, luers and rongeurs, using additionally a laminar spreader to ream all joint areas of the tibial, talar, medial and lateral malleolar facets. Cystic holes are reamed. If a bur is used cooling with cold saline is mandatory to avoid heat necrosis of the bone. If it becomes not clear if all sclerotic zones are resected the tourniquet has to be opend to proof if enough bleeding comes from the debrided joint surfaces. If not, more bone resection or multiple 2 mm Pridie drillings and/or microfracturing of the remaining sclerotic zone are

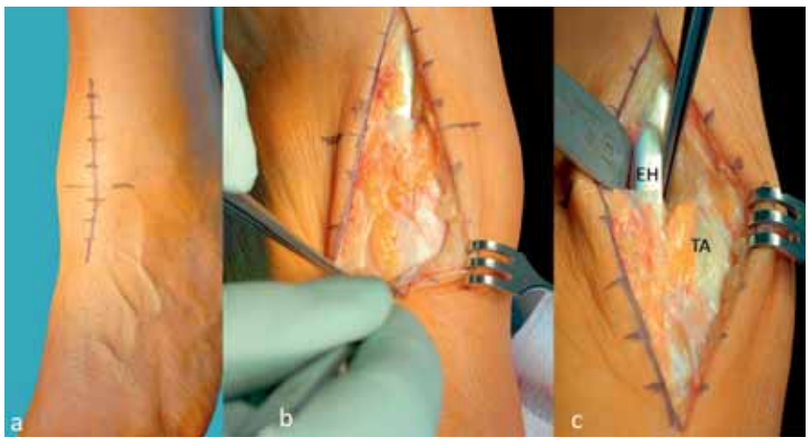

Fig. 5. The anterior approach to the ankle joint; a – the 6 to 7 cm long incision is marked in the mid-line two third proximal and one third distal to the palpable joint level; b – the proximal extensor retinaculum is incised in a zick-zack manner to enable readaptation at the end of the operation; c – dissection is performed between the extentensor hallucis longus tendon (EH) and tibialis anterior tendon (TA).

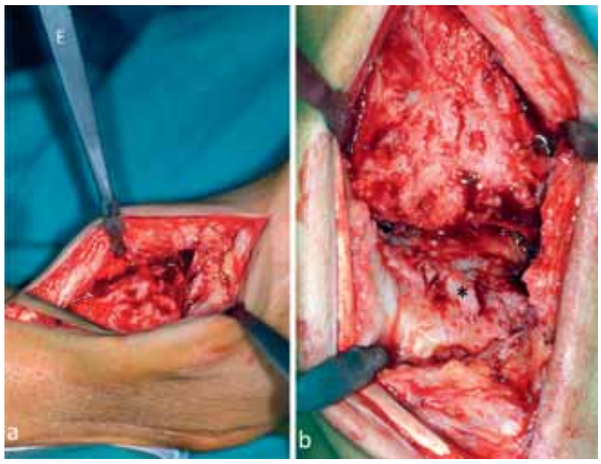

Fig. 6. The ankle joint area (a) is best exposed using two little sharp Eva-retractors (E), one medial, one lateral; b – remnants of cartilage (*) are removed as well as sclerotic bone.

Fig. 7. Typical varus deformity of the ankle joint with tilting of the talus (a) producing impaction and sclerosis at the medial tibial plafond accompanied by anterior shift (b) of the whole foot.

performed. In most cases a biomechanical malposition due to the anterior shift of the whole foot related to the ankle fork is given, being often combined with a chronic varus tilt of the talus (Fig. 7a, b). Therefore the dorsal capsule has to be resected radically through the open spreaded joint space. After this a sterile fulcrum has to be placed under distal tibia (Fig. 8) for pushing now strongly the whole foot posteriorly and fixing it in the reduced position temporarily with a 2.5 mm K-wire which runs percutaneously inserted from plantar through the calcaneus and talus into the distal tibia. Only in case that the fluoroscopic controls (Fig. 9a–c) show now that in the AP projection the talus is centered in the ankle fork without any tliting, that in the lateral view the lateral process of the talus is in line with the lateral axis of the tibia and that in the axial view the medial line of the calcaneus is in line with the AP tibial axis the two first two screws can be inserted. Otherwise more bone of the lateral, medial or dorsal tibial rim has to be resected repeating the whole procedure until both axis are radiological correct. Having this achieved the first

Fig. 8. After complete reaming of the whole joint, reduction of the foot posteriorly is best achieved by using a hard fulcrum, transfixing then the foot in the reduced position with a 2.5 mm K-wire from plantar through the calcaneus and talus into the distal tibia.

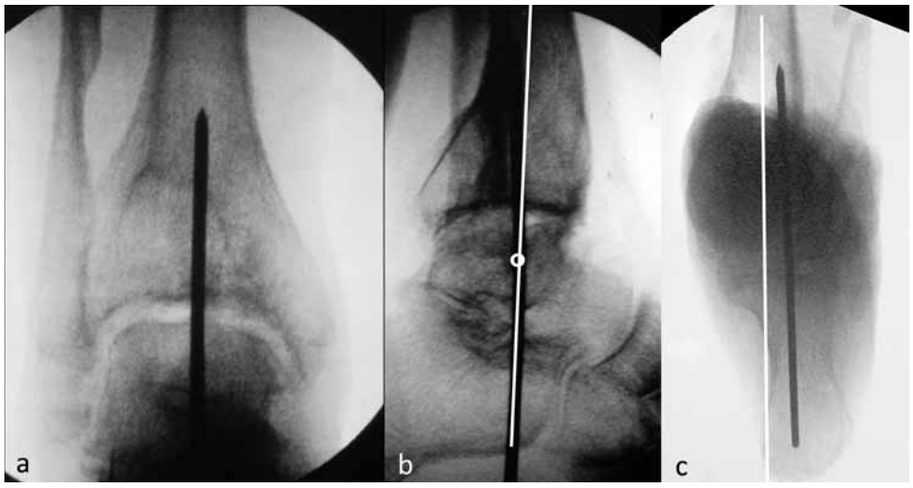

Fig. 9. The intraoperative fluoroscopic control should proof in the AP projection (a) that the talus is not any more tilted and centered in the middle of the ankle fork. The sagittal view (b) should show that the center of the corpus tali is right in the axis of the tibia. The axial view (c) should demonstrate that the alignement of the calcaneus with its medial wall is following the tibial axis.

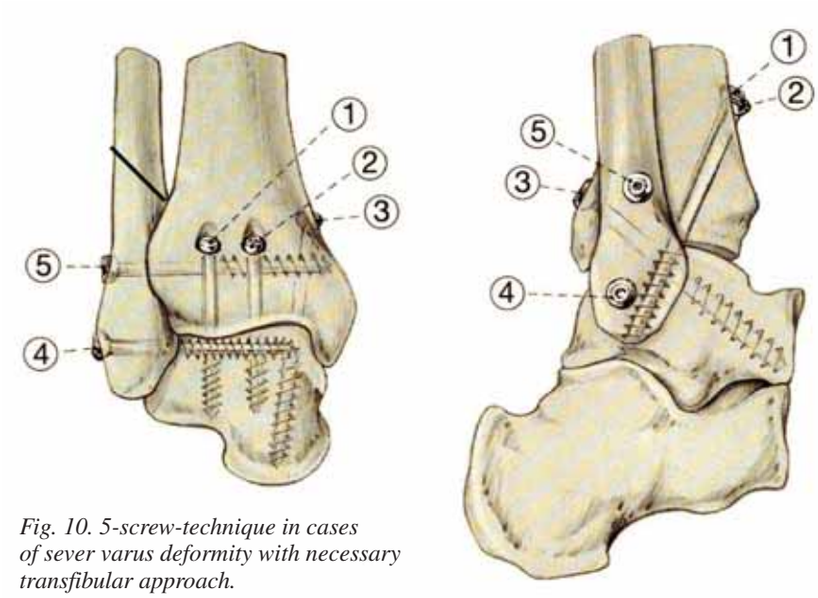

Fig. 10. 5-screw-technique in cases of sever varus deformity with necessary transfibular approach.

and second 6.5 mm titanium or steel screw with a 16 mm thread (Fig. 4a, b) respectively 7.0 mm cannulated ones are inserted from the open anterior approach very tangentially from the distal tibia into the middle part of the talar body. Predrilling of the whole length with the 3.2 mm drill is recommended. After this only the entrance of the drill hole should be overdrilled with the 4.5 mm drill and opened with the screw head reamer in order to place the big head of the screw less prominent. The screw length most often measures 45 to 50 mm. If some little varus tilt of the talus has to be still corrected one should start with the lateral screw, in case of some valgus with the medial one. Only in soft bone stock fully threaded 6.5 mm screws are used. The 3rd screw is inserted percutaneously as well as the lateral 4th one (Fig. 4c, d). For the 3rd screw which is considered as the biomechanical most important one, a longitudinal stab incision is made just at the palpable posterior rim of the distal tibia about 3 finger breadth proximal to the distal tip of the medial malleolus. With a small raspartorium one should free up the soft tissues of the dorsal site of the distal tibia in order to control that the posterior tibial tendon is not compromised by drilling the whole. This should run protected and guided by the 3.2 mm drilling sleeve from the posteromedial tibia to the anterolateral portion of the talar head. If positioned well the length equals most often 65 to 70 mm. Therefore always a 36 mm long thread of the 6.5 screw is used. For this somehow demanding drilling the assistant has to lift up the lower leg enough to give space and freedom for the correct targeting (Fig. 4c). The 4th screw is positioned also through a stab incision (Fig. 4d) which is located in the midline of the fibula about one thumb breadth proximal to the palpable fibular distal tip. The drill is guided right angulated to the fibula but a bit dorsally to run into the dorsal talar body. The length of this screw is most often 55 to 60 mm. Therefore also a 36 mm thread of the screw is always used to press the reamed talar facet of the fibula towards the lateral debrided facet of the talus.

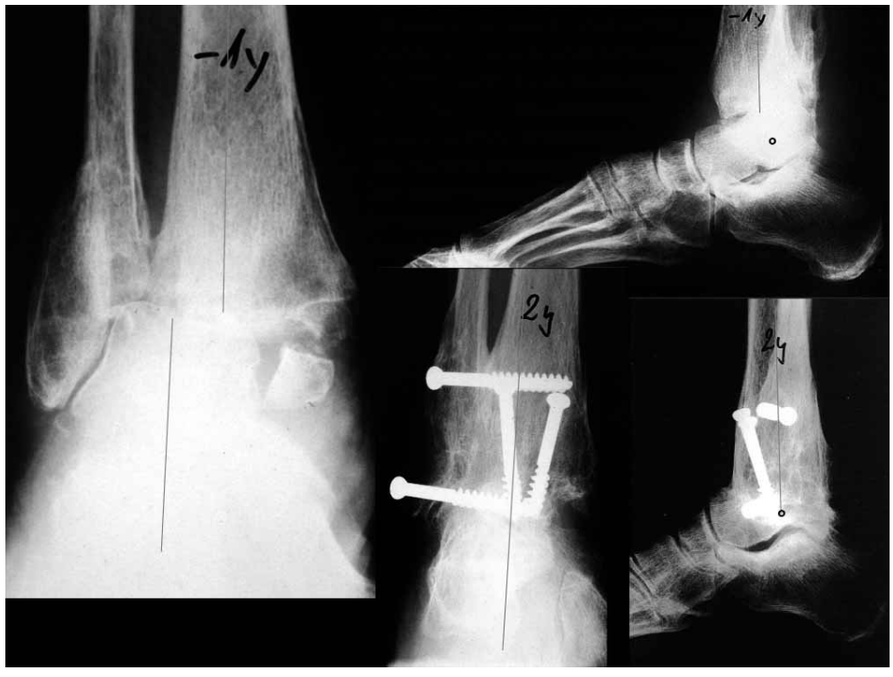

Fig. 11. This example shows what is understood as "reorientation" of the ankle in both planes: the severe malposition of all three components (lateral malleolus, medial malleolus and talus) which are shifted to the lateral side due to malunion of the lateral malleolus, non-union of the medial malleolus and the lateral following talus with foot has to be corrected by bringing back all three components to its original anatomic place before the debrided malleoli and talus are fused together with screws.

1b. Anterior 5-screw-technique

Only in cases of overlength of the fibula due to necessary bone resection of the sclerotic tibia (most often medially) an oblique osteotomy 3 finger breadth proximal to the distal fibular tip is made from proximal lateral to distal medial. Then a parallel resection of some millimeters related to the measured overlength is done and a fifth screw is used close distally to the osteotomy (Fig. 10). This oblique osteotomy is the same as for the transfibular approach in sever varus deformity (see below). In cases of severe ankle fork instability due to massive insufficiency of the distal syndesmotic complex like in malunited pronation-eversion fractures, pronation-abduction fractures or due to malleolar nonunion or malunion with translational malposition of the foot always two lateral screws are necessary (Fig. 11). The way of screw positioning or the use of cannulated screws is less important than the fact that reorientation of all axes must be achieved.

2. Transfibular 5-screw-technique

In cases of very severe hindfoot varus deformity due to varus deformation of distal fibula or chronic varus tilting of the talus within the ankle fork (Fig. 12a–e) anatomic correction is easier achieved by a transfibular approach. For this a longitudinal incision of about 10 cm over the middle part of the fibula is made 4 finger breadth cranial of the fibular tip running down to it. After having done the oblique osteotomy as described above the fibula is pushed dorsally allowing to ream the whole joint from this approach. Only in few cases an additional small longitudinal approach over the medial aspect of the medial malleolus is necessary to ream the medial corner. The "posteromedial" screw as shown in the standard 4-screw-technique can be substituted by an "anterolateral" screw which runs from the lateral talar process to the posteromedial part of the distal tibia (Fig. 12d, e).

3. Posterior approach and blade-plate fixation

In cases of significant instability of the ankle joint by primary bone loss like in open fractures or due to secondary bone necrosis with or without bone infection but necessary bone resection a 4- or 5-screw-technique, even a double plate fixation could result in a unstable osteosynthesis. Therefore a blade-plate-fixation via a posterolateral approach to the ankle joint with dorsal

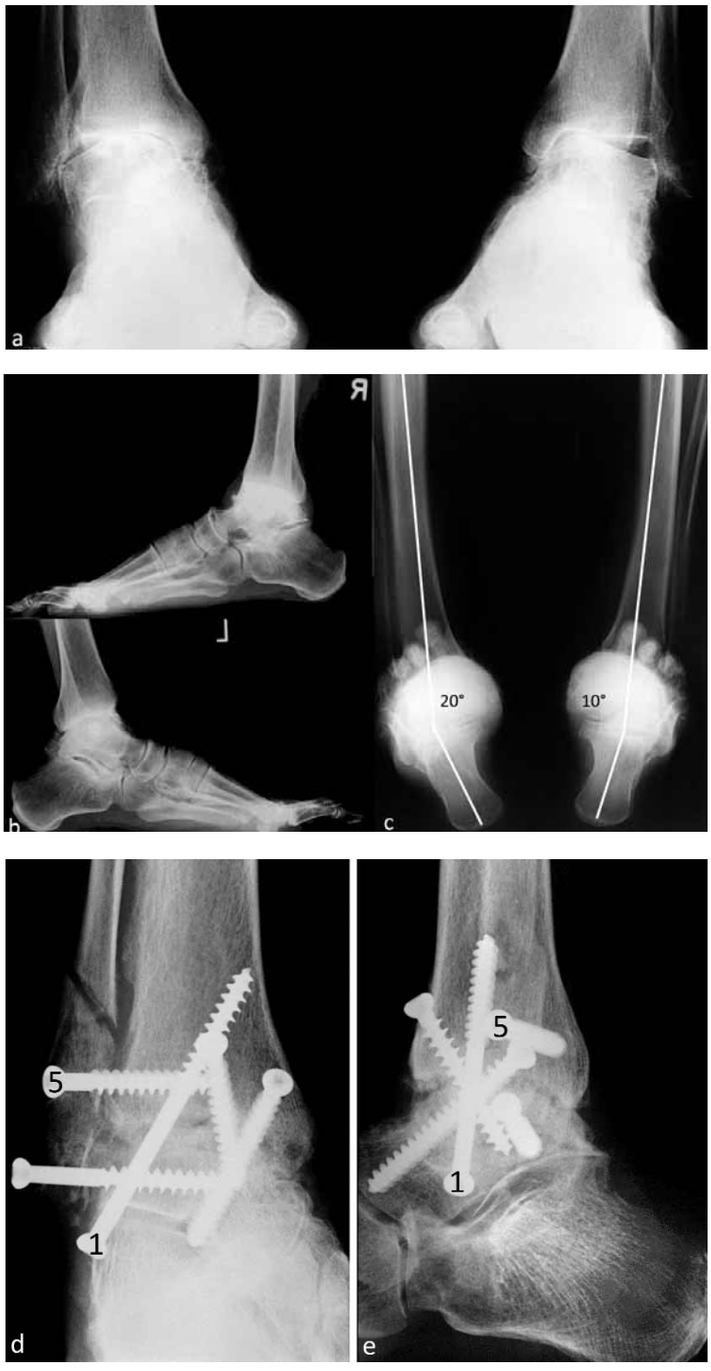

Fig. 12. Clinical example of a transfibular approach to the ankle joint; a – This method is chosen here because of the sever hindfoot varus deformity which is rightsided more than leftsided. The chronic varus tilting of the talus within the ankle fork causes sclerosis of the medial tibial plafond with big subchondral cysts in the talus; b – no sagittal shift of the foot is seen; c – 20° of hindfoot varus right, 10° left; d, e – the postoperative X-ray in both planes shows the "reorientation" with a corrected talus position without any tilt being centered in the ankle fork. By this transfibular approach with oblique osteotomy of the fibula it is easier to insert the first screw (1) not from the distal tibia into the talus as in the 4-screw-technique with anterior approach but from the lateral talar process into the tibia (1). For stabilization of the osteotomized lateral malleolus a fifth screw (5) is used principally.

Fig. 13. Example of an ankle arthrodesis performed via posterolateral approach and blade-plate-fixation. A 35-year-old male sustained after a suicidal jump from 10 m height multiple fractures including a third degree open Pilon-fracture with primary bone loss an skin defects ventrally. After general polytrauma management a debridement, artificial skingrafting and tibio-tarsal transfixation was initially done. a – the huge primary bony defect is visible; b – after 5 days a free flap coverage taken from the upper arm was performed; c – after several operations related to other fractures at least 20 days after polytrauma an ankle fusion via posterolateral approach, re-debridement, bone grafting and blade-plate-fixation was performed; d, e – Broden's view and lateral weightbearing view at the 1 year follow up show the perfectly healed ankle fusion, clinically a good function with 20 degrees of motion in the Chopart's joint and 1.5 cm leg shortening is seen.

blade-plate-fixation (Fig. 13a–e) is recommended especially when the anterior soft tissues are weak due to previous surgery or significant scaring caused by infec-tion. In case of a resected lateral malleolus used as local bone graft for the joint defect or due to previous resection because of bone necrosis but given intact lateral soft tissues, a laterally inserted blade-plate fixation is also performable.

4. Anterior approach and double plate-fixation

In cases of a necessary two-stage-procedure with debridement and temporary tibio-tarsal-transfixation because of infection, bone loss and need of secondary bone grafting a ventral double plate-fixation is recommended (Fig. 14a–d). The anterior approach for this osteosynthesis is the same as in the standard 4-screw-technique. After removal of the temporary external fixator and re-debridement the defects are filled with cancellous bone or bone blocks two 5-hole-titanium-plates (LCP 3.5 mm) are bowed intraoperatively over the middle hole. Most often a plate angulation is necessary adjusted to the normal 110° tibiotalar angle with fixing the talus with two screws through the distal wholes and the tibia through the two proximal wholes of each plate.

5. Modified Charnley-fixator-technique

In rare cases of signifcant osteitis or MRSA-infection of the ankle joint (Fig. 15a–d) a three stage procedure with a modified Charnley-fixator using threaded bars has been found as the method of choice. In a Charcot-Marie-Tooth patient with arthritis such a compression arthrodesis is a solid procedure performed as a one stage operation.

Aftertreatment

a) In case of stable screw fixation (methods 1 and 2) a Vario-Stabil-boot for 6 weeks is used allowing the patient to do full weightbearing in the boot as soon as no pain is felt, to take off the boot at night and at day for cleaning it and for exercises with the physiothera-pist.
b) In case of blade-plate or double plate fixation (methods 3 and 4) a lower leg cast for 6 weeks with partial weightbearing of 20 kg is recommended and for another 6 weeks the Vario-stabil-boot with increasing full weightbearing and exercises.
c) In case of the modified Charnley compression fixator (method 5) partial weightbearing of 20 kg for 6 to 8 weeks in an adapted shoe is recommended. After taking off the fixator a lower leg cast with full weightbearing for another 4 to 6 weeks is recommended.

Fig. 14. Example of an anterior double plate arthrodesis in a 70-year-old female. 9 months after a pronation-abduction fracture. The X-rays (a) show significant valgus with significant widening of the espace claire, shift of talus and foot laterally and no visible ankle joint space. The CT-scan (b) demonstrates tibial joint incongruency and questionable necrosis of the tubercule de Chaput, of the Volkmann fragment as signs of a low grade infection. Because of these findings and significant pain we decided for the first operativ step hardware removal using the pregiven bilateral approach combined with a short anterior approach. This approach facilitates the radical debridement of all necrotic bone with taking biopsies, the filling of the defects with Gentamycin-PMMA-beads and the control of a correctly positioned talus when adapting it with two screws and transfixing the joint with a central 2.5 mm K-wire and a tibo-tarsal external fixator (c). Eight days later having received negative probes re-debridement, autogeneous bone grafting and fusion with two ventral 3.5 mm titanium LCP with both 5 holes is done. Perfect bone healing in a biomechanical correct alignement of ankle and foot is seen in a painfree patient with clinical good function of the Chopart'joint at the 6 months followup (d).

RESULTS

We reported previously (34) about 72 patients and their 6-year-midterm results after ankle arthrodesis performed according the anterior 4- or 5-screw-technique. Not any deep soft tissue or bone infection was seen, only minor complications as superficial wound necrosis in 5% and a hematoma to revise in 3%. Bone healing

Fig. 15. Example of an ankle arthrodesis using a modified Charnley compression fixator in a 3 stage treatment with 3 approaches because of severe MRSA-infection of the ankle and subtalar joint. A 59-year-old male sustained multiple fractures in Italy and showing up in our hospital 3 months after polytrauma and several revisions of the ankle joint with a painful ankle and tiny fistula. The nailed tibia (a) was meanwhile more or less radiologically healed, the talus due to MRSA-infection looked white being suspected as a septic necrotic bone. The first step of this arthrodesis included hardware removal of the tibial nail and the K-wires in the fibula using the proximal tibial approach and an anterolateral plus posterolateral approach to the ankle for removing the PMMA-beads, excision of the fistula, bone biopsies and a very radical debridement. Finally the ankle joint and hindfoot were stabilized with the Charnley compression fixator inserting two Steinmann-pins with central thread into the tibia and two into the calcaneus setting the ankle joint space under compression with the two threaded bars of the system (b). In the second step after five days a radical re-debridement of the ankle joint was done combined with an addiditional debridement of the subtalar joint and installation of a permanent biclin-lavage of the MRSA-infected ankle and subtalar joint for 8 days. In the third step the permanent biclin-lavage-system was removed and a third debridement of the ankle joint was performed combined with filling the defects with autogeneous bone graft giving finally some more compression to the ankle and subtalar joint via the threaded bars. After 6 weeks some more compression was applied and after three months the arthrodesis was consolidated allowing removal of the Charnley fixator as an outdoor patient procedure. The radiological follow-up at 3 years (c, d) showed a solid healing of the hindfoot fusion and a well aligned ankle with foot. The patient was clinically painfree and had some amount of motion in the Chopart`s joint. According to a recent phone questionnaire no recurrency of infection after 20 years was reported.

was observed in 99%, this within 8 ± 2 weeks. The only one non-union seen occured in a patient with a not diagnosed Charcot-Marie-Tooth disease at time of surgery. The 6 years followup showed an increase of the AOFAS ankle/hindfoot score (17) from intial 36 to 85 points in average. The mean sagittal range of motion of Chopart's joint measured under maximal active dorsiflexion and plantarflexion radiographically 24° ± 16°. The radiographic signs of arthritis had progressed in 25 of 72 patients (35%) in the subtalar joint and in 13 of 72 patients (18%) in the talonavicular joint. In cases in which not any arthritis was seen radiographically in the subtalar or in the talonavicular joint just before performing the arthrodesis, arthritis was seen only in 12 of 72 patients (16.6%) in the subtalar joint and in only 8 of 72 patients (11.1%) in the talonavicular joint. Only 7 of 72 patients (10%) had a mild residual varus deformity of 1° to 5°.

Other much more problematic cases (n = 9) which were not included in the previous study (34) are shown casuistically in this paper being treated differently with blade-plate, 3.5 mm double plates or with a modified Charnley-fixator-technique. They all needed in minimum a two stage procedure and autogeneous bonegrafting. All healed in averaged time of 12.5 ± 4 weeks, only one healed delayed after 6 months by use of pulsed ultrasound and another did not heal within 9 months but finally 6 months after secondary hindfoot nailing. Both belonged to four cases after failed ankle replacement needing huge boneblocks (33).

DISCUSSION

Ankle arthrodesis is an established treatment method for end-stage symptomatic ankle arthritis. In most cases the 4-screw-technique is possible and considered as an ideal procedure. By avoiding any resecting saw cuts and reaming only the joint spaces by leaving the whole ankle fork intact, failures of varus, valgus or rotational malalignement are avoidable in almost all these cases. In contrast to this it was seen in an early own study (31) when we resected parts of the tibial plafond and the medial malleolus, osteotomizing and shortening the fibula with shift of the talus far posteriorly and fixing the arthrodesis with a compression fixator as recommended by AO (19) that a high rate of malalignement like significant varus, valgus, equinus or internal malrotation was produced in 50% (37 of 74 patients) and nonunion in 4%. Since using the 4-screw-technique we observe in opposite to this only mild malalignements in 10% and non-union in 1% (34).

Looking into literature related to biomechanics and the nowadays prefered screw technique the number of screws used seems also to be relevant for proper bone healing. This was recently stressed out by Goetzmann et al. (12) who reported in a radiographic study of 111 cases a 16% non-union rate when using only two screws and 6 % when using 3 screws in combination with arthroscopy. In addition a cadaver study (16) has shown that each threaded screw, equal if medially, laterally or dorsally placed, leads to 11% of joint surface contact. If a fourth threaded screw would lead to another 11% of joint surface contact was not proofed but seems to be reasonable, especially when the 4 screws are placed in 3 planes like in the own 4 screw-technique. Hoover et al. (15) compared in an experimental study a bimalleolar external fixation to conventional crossed-screw construct and found high significant differences for the mean peak load to failure and the ultimate torque testing in favor to the external fixator.

Comparing results of ankle arthrodesis in the literature of the last 20 years there are most reports below 50 patients followed up. There are only two British papers found reporting numbers above 50 followed patients, one by Winson et al. (30), one recently by Gordon et al. (13). Winson et al. (30) performed arthrodesis arthroscopically with screw fixation in 105 patients, but the follow up at 5 years and 5 months was done only by phone. They found an union rate of only 92% with 3% minor wound healing problems, but 2% major complications like one deep infection and one stress fracture with fusion in equinus In our study with the mini-open approach and the 4-screw-technique in 72 patients the union rate was 99% and the minor wound healing problem rate 8%. The 7% higher fusion rate in our collective might be due to the mini-open visualization having a better approach for different instruments allowing a radical debridement of all sclerotic zones. Gordon et al. (13) found in a midterm followup of 4 years in 57 patients a higher AOFAS score of 93 points compared to ours of 85 points. They used similar to us an anterior open approach and found a 100% bone healing rate within an averaged time of 13.3 weeks but 14.6% major complications. Compared to our study we observed a similar bone healing rate of 99% but with a 5 week shorter bone healing time of averaged 8 weeks and not any major complication. In 1991 Myerson and Quill (20) compared two small groups related to bone healing time. This was 8.7 weeks in the arthroscopic arthrodesis (n = 17) and 14.5 weeks in the open arthrotomy with malleolar ostectomy group (n = 16). These findings are contradictory to our bone healing time of 8+/-2 weeks in average in a larger group of 72 patients with the mini-open 4-screw-technique. The different procedures of preserving principally the malleoli, the 4-screw-technique with higher primary stability and the functional aftertreatment in a boot with early full weightbearing in our patients could be considered as stimuli of bone healing.

Related to high range of motion in the midtarsal joint we concur with Takakura et al. (27) that shorter periods of immobilization (about 6 weeks) after ankle arthrodesis lead to increased range of motion at the subtalar and midtarsal joints as compared with longer times of immobilization of 12 to 15 weeks (5, 7, 24). Furthermore due to the high primary stability using the 4 screw fixation we don't really immobilize our patients because we don`t use a lower leg cast but a removable boot which protects the ankle for 6 weeks during walking. This boot allows early motion of Chopart's joint while walking with the flexible sole. It can be taken off at night and at day for exercises with the physiotherapist. All together promotes Chopart-joint movement and explains the high range for dorsiflexion and plantarflexion of 24° ± 16° what is considered as absolutely enough for normal walking (26).

Several long-term studies have reported high overall rates of subtalar arthritis of between 47% and 100% (4, 7, 10, 11) but all of these studies included a high rate of ankles which were fused in either a varus, valgus, equinus or rotational malposition. We believe that the low rates of 16.6% subtalar arthritis and 11.1% of talonavicular arthritis in our patients developed within 6 years of followup combined with a high rate of union (99%), a high rate of midtarsal motion (24° ± 16°) and a high AOFAS-score of 85 is due to the precise fusion technique respecting both planes of the talus related to the lower leg which is expressed by the term of "reorientation". Only by these intraoperative exactly followed rules pathological strain to the adjacent joints can be avoided and by this the so called "transfered arthritis".

Meanwhile consensus is achieved in literature that a neutral position in the sagittal plane, neutral to slight valgus (5°) in the coronal plane and 5° to 10° external rotation in the horizontal plane with the talus centered exactly below the tibia (1, 8, 18, 29) is essential for good outcomes with less strain to the adjacent joints including the knee.

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