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3D Imaging (ARCADIS)-Based Computer Assisted Surgery (CAS) for Nail Placement in Combined Ankle and Subtalar Fusion

Martinus Richter, MD, PhD; Stefan Zech, MD; Raymund Bay, MD
Coburg, Germany

Level of Evidence: V, Expert Opinion

INTRODUCTION

The correct placement of a retrograde nail for fixation in a combined ankle and subtalar arthrodesis especially in the presence of deformity be difficult.[2–4] We have previously introduced a 2D imaging-based CAS guided drilling for nail placement.[6,7] The 2D imaging-based CAS guided correction positioned the calcaneus in relation to the talus and/or the tibia.[6,7] Due to difficulties in planning and potential inaccuracies, we have switched to a 3D imaging-based method for the drillings.[6,7] We hypothesize that a 3D imaging-based CAS guided drilling for this purpose is more accurate that the 2D imaging-based CAS guided method because this has previously been shown for CAS guided retrograde drilling in osteochondritis dissecans of the talus.[1,9] Another advantage of this method is that the 3D imaging before insertion of the implant allows better assessment of the correction than 2D imaging.[6,7] This new method of 3D imaging (ARCADIS)-based CAS guided drilling for nail placement in a combined ankle and subtalar arthrodesis with deformity correction is introduced (model ARCADIS, Siemens Medical Inc., Munich, Germany, and model Navivision, Brainlab Inc., Heimstetten, Germany).

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Corresponding Author:
Martinus Richter, MD, PhD
Klinik für Unfallchirurgie, Orthopädie und Fusschirurgie
Klinikum Coburg
Ketschendorfer Str. 33
96450 Coburg
Germany
E-mail: info@foot-trauma.org
For information on prices and availability of reprints, call 410-494-4994 x226

OPERATIVE TECHNIQUE

A retrograde intramedullary rodding of partial avascular osteonecrosis of the talar body, posttraumatic ankle and subtalar joint osteoarthritis with correction of a varus deformity of the ankle (13 degrees in comparison with the normal contralateral side) after a talar fracture is presented. The patient was placed in the prone position. A posterolateral approach was used. Since no deformity between the calcaneus and talus existed in this case, the position of the calcaneus in relation to the talus was temporarily fixed with two 2.0-mm titanium Kirschner wires after cartilage removal of the posterior facet. Titanium was used to minimize the artifact for the 3D imaging. The correction of the transfixed talus/calcaneus unit in relation to the tibia was performed with 2D imaging-based CAS guidance as previously described.[6,7] During the CAS guided correction, bone grafting with two autologous tricortical bone blocks and autologous cancellous bone from the posterior iliac rim was performed.

Transfixion between the calcaneus, talus and tibia was achieved by advancing the Kirschner wires. The use of autograft is the standard technique in the country in which this procedure was performed. Patients in general and this individual patient usually decline allograft despite the morbidity of obtaining the autograft. The bone blocks were placed in a large defect of the talar body due to the avascular necrosis. Then the Dynamic Reference Base (DRB) from the tibia was removed to minimize artifact. The DRB in the talus was left in place. The 3D imaging dataset was obtained by ARCADIS-scan (Figure 1). Before the scan, the 2D navigation cage that was earlier needed for the CAS guided correction was removed and the entire table was draped with a sterile plastic bag. With the 3D reformations, the accurate correction of the position of the calcaneus/talus in relation to the tibia was confirmed (Figure 1, B and C). Drilling was planned with a starting point at the inferior margin of the calcaneus in the exact axis of the tibia in the parasagittal plane, and 1cm lateral from the tibial axis in

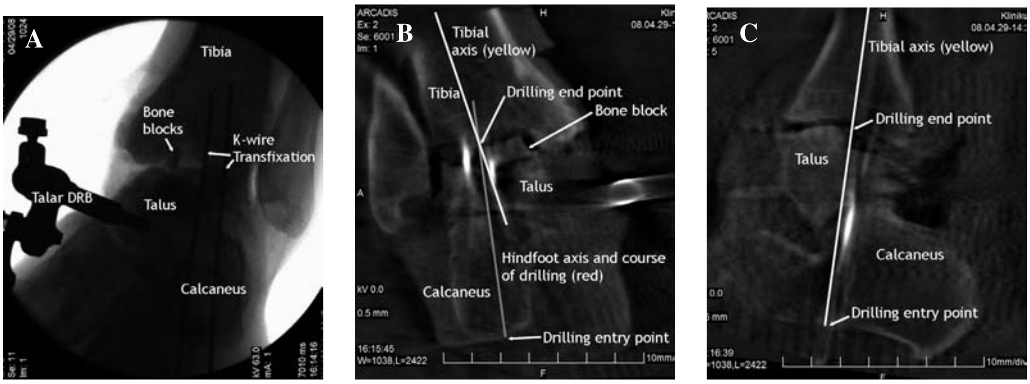

Fig. 1: Intraoperative image acquisition with ARCADIS. **A**, A 2D-image without sufficient visualization of the drilling entry- or endpoint. **B** and **C**, One coronal reformation (B) and one parasagittal reformation (C) of the 3D-dataset from the ARCADIS scan with good visibility of the entire course of the planned drilling, and good assessment of the earlier correction.

the coronal plane (Figure 2, A and B). The lateral shift of the starting point respects the lateral bend of the implant (model Distal Femoral Nail, Synthes, Umkirch, Germany) which results in 1 cm lateral deviation from the tibial axis resulting in 5 degrees valgus position (Figure 2A). The planned endpoint of the drilling was the center of the talar dome at the exact point of intersection of the tibial axis in the parasagittal, coronal and axial planes. Then the drilling was performed with a CAS guided 4.5-mm drill (Figure 3). The Kirschner wires and DRB were removed. The standard guidewire of the implant was inserted in the drillhole and advanced into the tibia. For the introduction of the wire into the tibia, inversion in the ankle was performed to straighten the course of the guidewire. Then the reaming was performed, the nail was inserted, and the locking screws introduced in the standard manner.[5] Three-dimensional ARCADIS imaging was performed to analyze the correction of the deformity and screw position (Figure 4). The process of CAS guided drilling, reaming and insertion of the nail took 6 minutes. The entire surgery took 118 minutes. The image exposure is comparable to 104 pulsed digital fluoroscopic images or 42 seconds pulsed fluoroscopic imaging. Half of this radiation exposure had been done in the case of 2D screw navigation also, because one ARCADIS 3D scan is usually performed to assess bone and implant position after 2D navigation. During the 3D imaging (100 of the 104 images), the entire operating room staff left the area of radiation contamination before scanning.

DISCUSSION

One of the most important issues in extended hindfoot fusion is to obtain a correct and stable position of the foot. In most instances, there are difficult conditions such as bone loss, deformity, and instability. However, implant position plays a significant role for getting a reliable result. This technical tip does not focus on the problem of bone loss or deformity but on correct implant positioning. The problem of bone loss was addressed by using bone autograft extensively; the problem of deformity was addressed by using CAS guidance for the correction; and the problem of stability was addressed by using the retrograde locking nail. A distal femoral nail was used with a long curved 5-degree bend. This nail is normally used as a retrograde nail for the distal

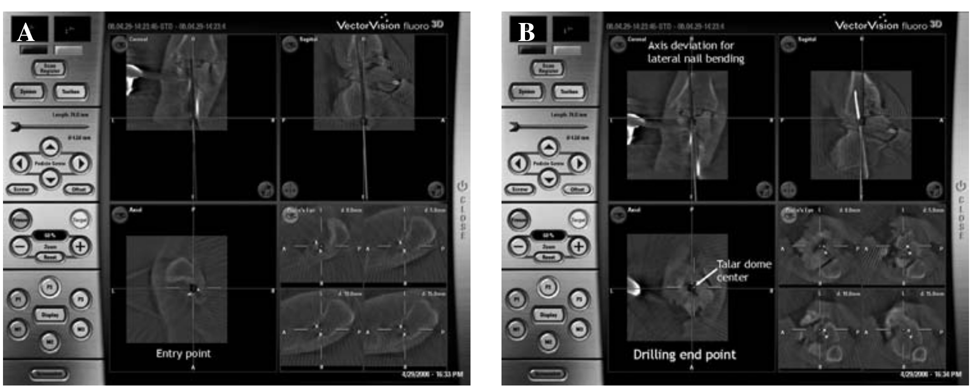

Fig. 2: Planning of the drilling with the Vectorvision fluoro 3D software. A virtual screw with the planned length and diameter of the screw (4.5 mm) is placed digitally by the surgeon on the screen of the CAS device. **A**, Exact planning for the entry point. **B**, The planning for the endpoint.

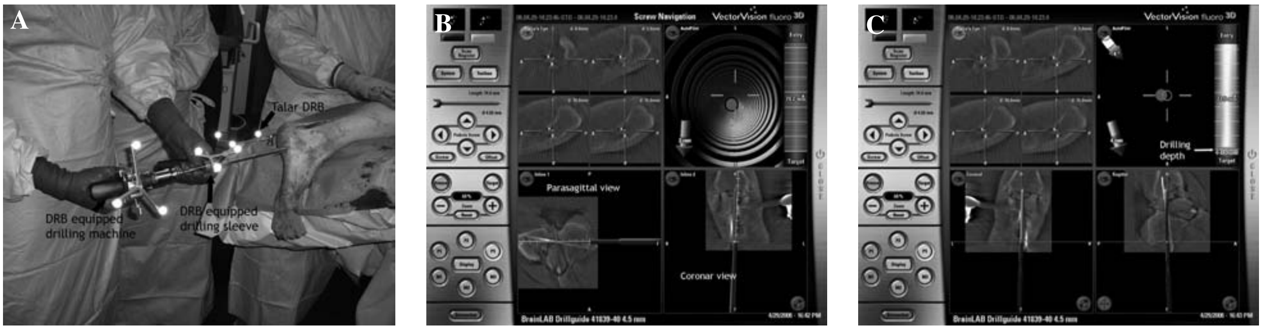

Fig. 3: Retrograde drilling with a starting point at the inferior margin of the calcaneus in the exact axis of the tibia in the parasagittal plane, and 1cm lateral from the tibial axis in the coronal plane. The endpoint of the drilling was the center of the talar dome at the exact point of intersection of the tibial axis in the parasagittal, coronal and axial planes. Figure 3A shows the intraoperative appearance. Figures 3B and C show the screen of the CAS device with an axial reformation, a parasagittal reformation, four axial reformations at different depths, the "aiming worm", and a display for the planned and achieved depth. The "aiming" worm contains a red point and a virtual worm leading to that point. This visualization animated the surgeon to hit the red point which results in correct direction and depth of the drilling. Figure 3B shows the drilling at the beginning, and Figure 3C the drilling at the end with the planned depth. The drilling sleeve with a DRB is important for the correct direction of the drilling, and the drilling machine is necessary to navigate the depth of the drilling.

Fig. 4: Control of accuracy of the remaining correction after nail insertion and locking with a second 2D- and 3D-ARCADIS scan showing the exact course of the nail as planned (**A**, 2D anteroposterior view; **B**, 3D coronal reformation; **C**, 3D parasagittal reformation; **D**, 3D axial reformation). The AP view shows the bend of the implant with a lateral shift of the entry point in relation to the tibial axis.

femur and the bend respects the physiological curve of the femur. We used the nail in a manner such that the bend was directed laterally to place the foot into physiological valgus. The locking screw hole distance of the distal femoral nail is too large to insert both locking bolts into the calcaneus; the distal one is inserted into the calcaneus and the proximal one into the talus. The correct placement of this and any other retrograde nail in a combined ankle and subtalar arthrodesis can be difficult especially in the presence of deformity. We have previously introduced a 2D imaging-based CAS guided drilling for the nail placement.[6,7] Due to difficulties in planning and potential inaccuracies, we have switched to a 3D imaging-based method for the drilling. Nail insertion was accurate in this case. We feel that this method can be the standard for validation of navigated techniques in the future.

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