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3D Imaging (ARCADIS)-Based Computer Assisted Surgery (CAS) Guided Retrograde Drilling in Osteochondritis Dissecans of the Talus

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INTRODUCTION

The goal in osteochondral defects of the talus in Stages I and II according to Berndt and Harty is revascularization of the lesion.[3] A debridement of the chondral part is required if symptomatic.[1,24] This debridement is limited to loose cartilage or cartilage with poor quality.[1,22,24]

Subchondral drillings of the lesion allow a revascularization. Retrograde drillings leave the chondral surface intact and are advantageous compared with antegrade drillings.[5] Arthroscopically guided drillings are limited to those lesion that could be arthroscopically identified.[22] In the remaining cases open procedures are justified.[21] Based on these principles, computed tomography (CT)-based Computer Assisted Surgery (CAS) guided retrograde drilling of osteochondral lesions has been described with promising results as a new technique.[5,20] CT- and fluoroscopy-based navigation systems in current use are limited in their flexibility.[15] The drawback of fluoroscopy is the lack of 3D imaging intraoperatively. CT-based navigation still requires intraoperative cumbersome registration, extra preoperative planning, and imaging with further technical resources.[18] In addition to the current method of arthroscopic evaluation and treatment, we earlier introduced an alternative technique of using 3D imaging with ISO-C-3D (Siemens Medical Inc., Munich, Germany)-based CAS guided retrograde drilling of the lesion.[18] This method was feasible, accurate, and showed good clinical ourcome.[16,18] However, the technical equipment of the earlier 3D-imaging devices (model ISO-C-3D, Siemens Medical Inc., Munich, Germany) and CAS devices (Model Surgigate, Medivision Inc., Oberdorf, Switzerland & Northern Digital Inc., Waterloo, Ontario, Canada; Medivision later sold an renamed in Praxim Inc., Grenoble, France) was somewhat cumbersome in handling and error-prone.[16,18] These devices were further refined for easier and faster handling are less prone to error. We introduce a 3D-based CAS guided retrograde drilling technique with a combination of these actual devices (model ARCADIS, Siemens Medical Inc., Munich, Germany; model Navivision, Brainlab Inc., Heimstetten, Germany).

OPERATIVE TECHNIQUE

A 34-year-old salesman with an OCD Stage II according to Berndt & Harty and Stage IIa according Hepple/Winson at the medial talar shoulder was treated (Figure 1).[3,8] An arthroscopy confirmed the diagnosis (Figure 2). The cartilage was intact but softer than the surrounding cartilage. In the same procedure, a Dynamic Reference Base (DRB) was fixed to the talar head through a small incision (Figure 5A), and an intraoperative image acquisition with ARCADIS followed (Figure 3). The 2D images were solely obtained to show the insufficient visibility of the OCD lesion on 2D images for this publication.[4,18] The retrograde drilling was planned with a starting point at the lateral talar process and an endpoint in the subchondral sclerosis exactly beneath the intact cartilage (Figure 4). Then the drilling was performed with a 4.5-mm drill (Figure 5, A and B). The subchondral sclerosis was removed during the drilling as part of the drilling flour. After the drilling, a 1-mm titanium Kirschner wire was inserted in the drillhole, and 2D- and 3D-ARCADIS imaging was performed (Figure 7). Then, the Kirschner wire was removed and autologous cancellous bone graft that was obtained from the ipsilateral distal tibia was inserted. Arthroscopy

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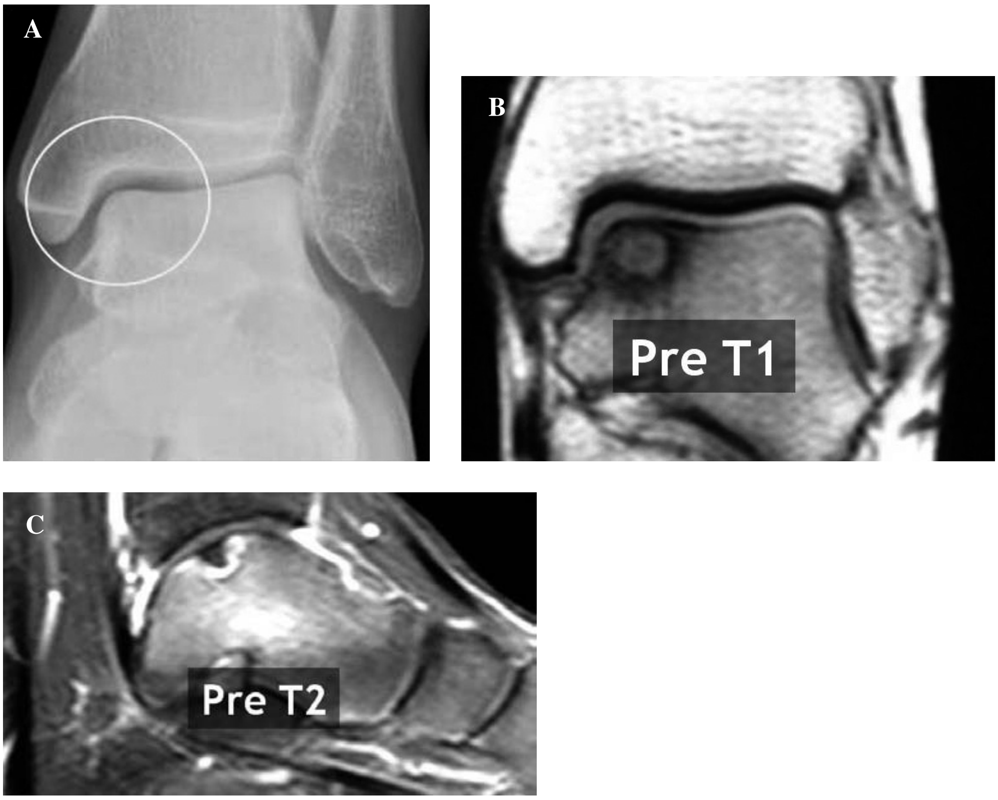

Fig. 1: Radiograph and MRI images of an osteochondrosis dissecans (OCD) tali at the medial talar edge (Berndt and Harty Stage II, Hepple and Winson Stage IIa): AP radiograph (A), coronal T1 reformation (B), and parasagittal T2 reformation (C).[3,8]

proved the intact and stabilized cartilage after drilling and bone grafting. The time needed for the entire procedure was 45 minutes. The image contamination is comparable to 104 pulsed digital fluoroscopic images or 42 seconds pulsed fluoroscopic imaging. Figure 8 shows MRI images at 2-year followup with intact cartilage an incorporated bone graft.

DISCUSSION

There are several options available for the operative treatment of osteochondritis dissecans Stage I and II at the posterior medial talar edge (Berndt & Harty).[1,7,22,24] One favorable option is the retrograde drilling.[1,7,22,24] An open procedure requires an extensile approach including osteotomy of the medial malleolus.[21] Minimally invasive techniques have been developed with fluoroscopically based aiming devices.[1,22,24] Arthroscopic based techniques require an arthroscopically detectable and reachable lesion that might be problematic in early stage lesions at the posterior medial talar edge.[1,22,24] To date, sufficient inspection of the entire joint is possible due to improved technical features of the arthroscopes (smaller diameter, better image quality). However, the identification of the exact location and size of early stage defects is still problematic even for experienced

Fig. 2: Arthroscopic image before drilling showing intact but soft cartilage.

"arthroscopist" with modern equipment.[23] The use of CT-based CAS guided retrograde drilling was introduced for those cases.[2,5,10,20] This method requires preoperative CT data that are transferred to the navigation system. Then, the preoperative data are synchronized with the intraoperative field in a so-called matching process. This methological

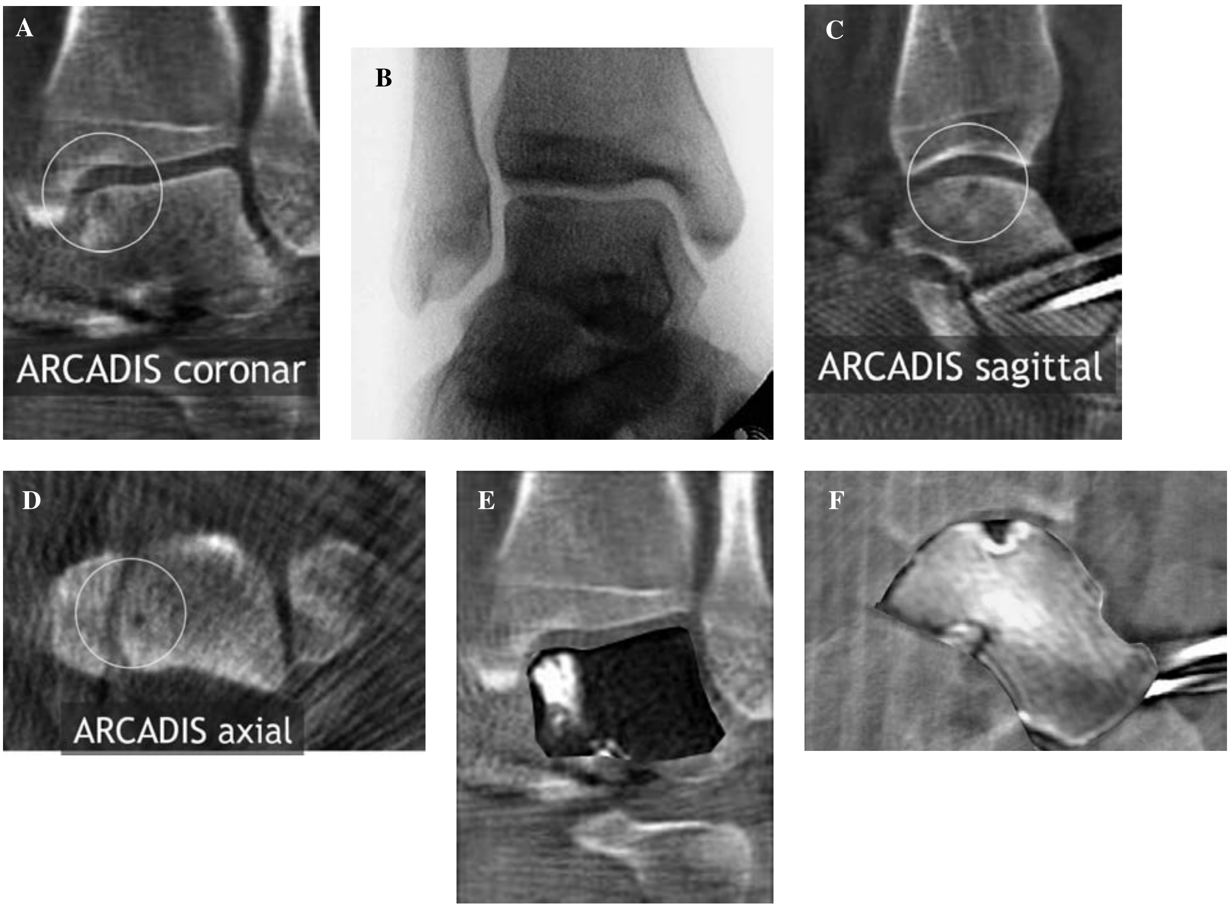

Fig. 3: Intraoperative image acquisition with ARCADIS. **A**, A 2D-image without sufficient visibility of the OCD lesion. **B** to **D**, The reformations of the 3D dataset from the ARCADIS scan with good visibility of the OCD lesion. **E** and **F**, An optional image fusion of the MRI image and the ARCADIS 3D-refomation for better visualization (E, Fusion of coronal MRI T2 image of the talar body with a coronal ARCADIS 3D reformation; F, Fusion of parasagittal MRI T1 image of the talar body with a parasagittal ARCADIS 3D reformation).

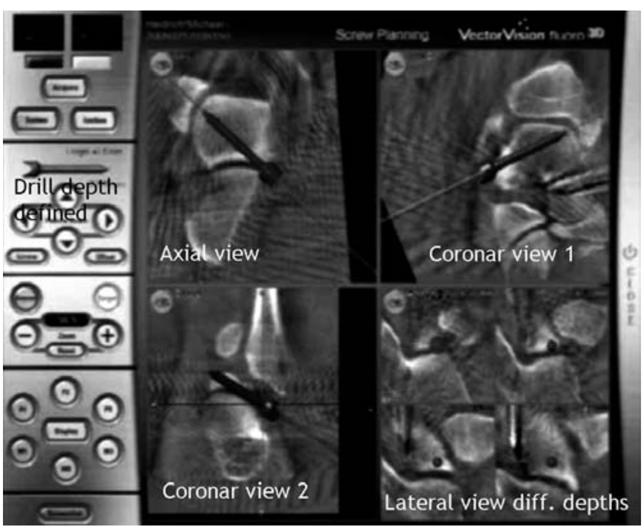

Fig. 4: Planning of the drilling with the Vectorvision fluoro 3D software. A virtual screw with the planned length and diameter of the drill (4.5-mm diameter shown here) is placed digitally by the surgeon on the screen of the CAS device.

issue causes the main problem of the CT-based CAS in the foot.[15,18] The main problems with the matching are based on the difficult bony architecture of the foot with 28 bones and more than 30 joints. Due to these anatomic conditions, the foot does not remain in the same position between the preoperative CT and the registration. This makes the registration in the foot much more difficult than in other body regions like the spine or the pelvis with lesser and bigger bones.[15] Two novel CAS methods without necessary registration were designed, the C-arm-based CAS and the ISO 3D.[15,16,18] In both, the C-arm and ISO-3-D based CAS, the data is gathered intraoperatively. The DRBs (Dynamic Reference Base) are fixed to the bones before, which makes matching unnecessary. Both methods combine the accuracy of the CT-based CAS without the stumbling block of "matching".[15,16,18] The C-arm-based CAS provides only 2D images. This is problematic for three dimensional aiming as necessary for retrograde drilling in osteochondrale lesions of the talus.[4,18] For this purpose the ISO 3D-based CAS guided drilling is more favorable.[4,18] It has been shown in vivo and in vitro that the 3D imaging method

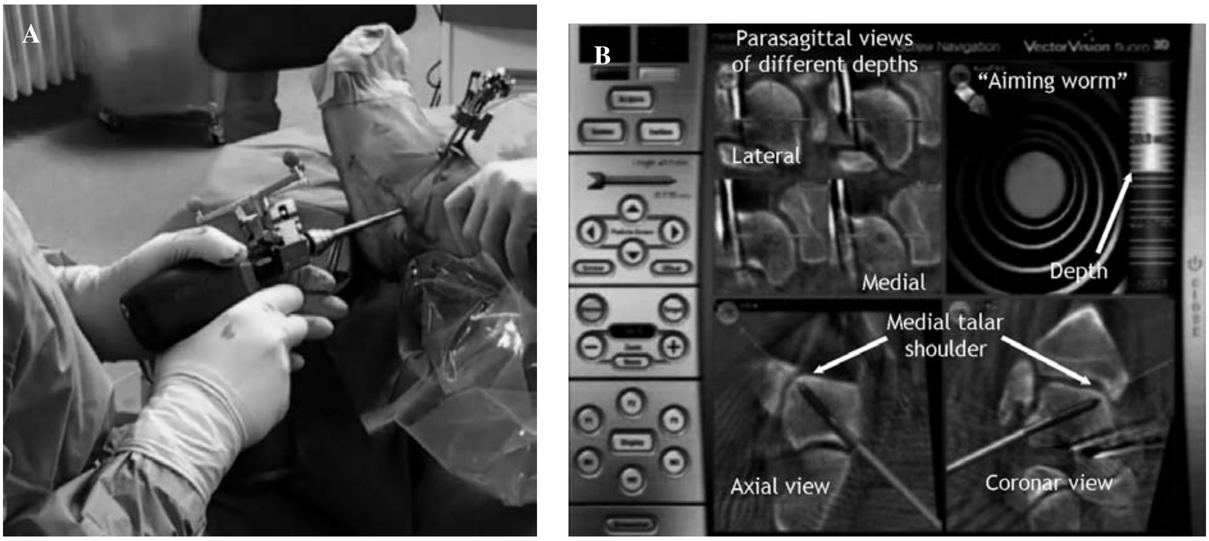

Fig. 5: Retrograde drilling with starting point at the lateral talar process and visualization on the screen in real time. **A**, The operative field is shown. **B**, The screen of the CAS device is shown with an axial view, a coronal view, four parasagittal views in different depths, the "aiming" worm, 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 guided the surgeon to hit the red point which results in correct direction and length of the drilling.

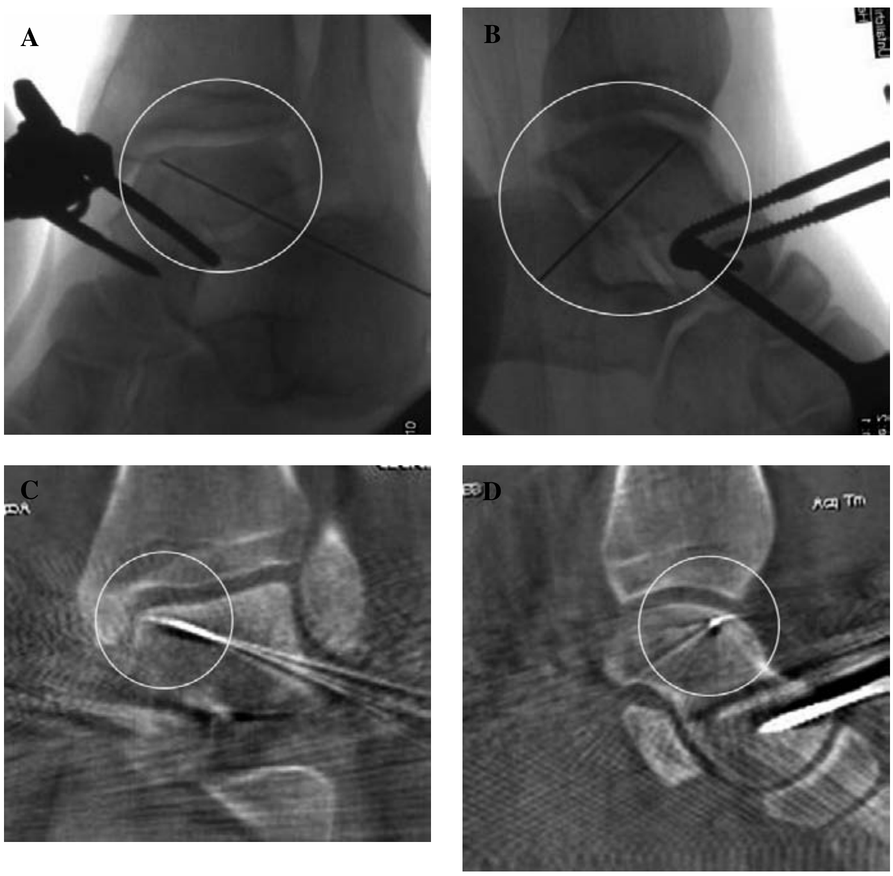

Fig. 6: Control of accuracy of the drilling with a second 2D- and 3D-ARCADIS scan after insertion of a Kirschner wire in the drillhole showing the exact course of the drilling as planned before. The black areas around the Kirschner wire correspond to artifacts and is not equivalent with the diameter of the drilling (**A**, 2D AP view; **B**, 2D lateral view; **C**, 3D coronal reformation; **D**, 3D parasagittal reformation).

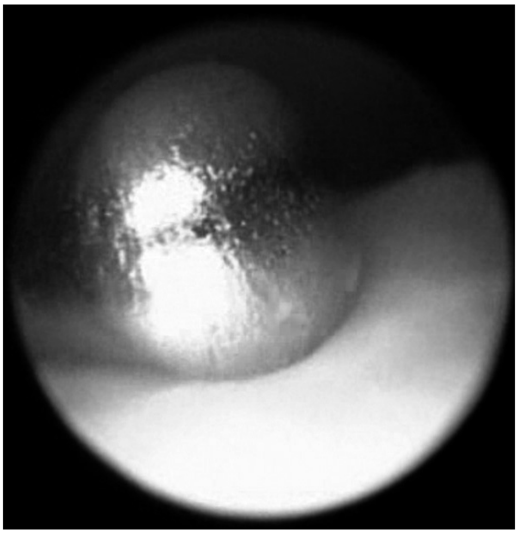

Fig. 7: Arthroscopic control after drilling and autologous cancellous bone graft showing intact and stable cartilage surface.

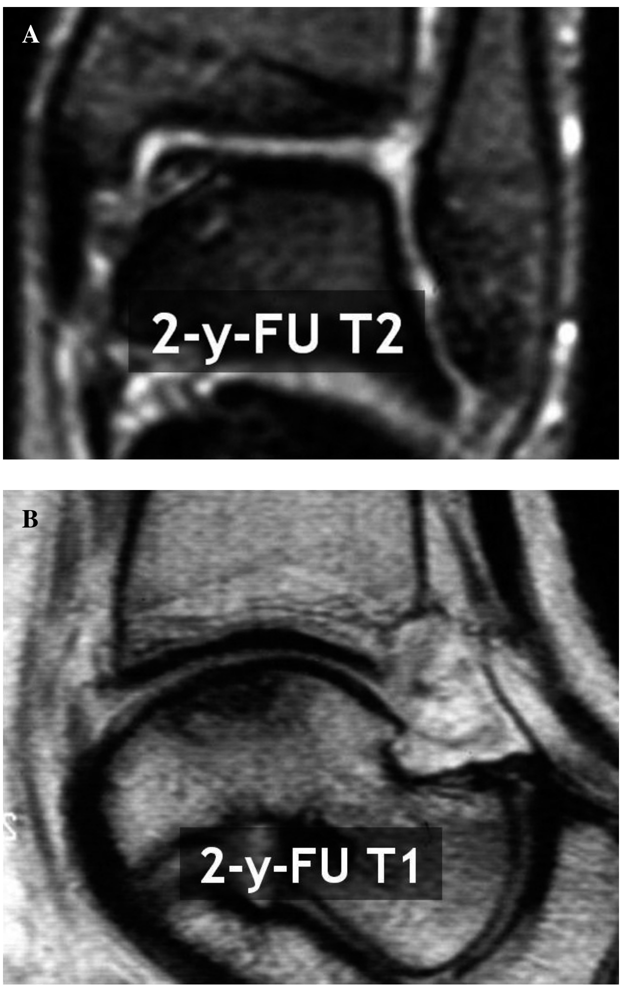

Fig. 8: MRI followup: coronal reformation (A) and parasagittal reformation (B).

is clearly superior to the 2D imaging-based method.[4,18] However, the handling of this system was very complex. The devices were further refined for much easier and faster handling with less prone to error. The actual ARCADIS-based CAS worked without problems in the described case. We chose a 4.5-mm drill because this was the thickest drill that was available for navigation at the time of the surgery (2004). Studies suggest that drillbit deflection interferes directly with the precision. The precision is decreased when using small diameter and longer drill bits.[11] To date, we use the thickest drill available (5 mm) for the Brainlab system.

Another important issue is the device cost, which is much higher for the ARCADIS-based CAS (500,000 Euro) than for arthroscopy systems. These huge device costs for the ARCADIS-based CAS will prevent standard use for retrograde drilling in osteochondral lesions of the talus alone despite the advantages. However, the ARCADIS-based CAS is also useful for other body regions like spine and pelvis.[9,13,14] Furthermore, the ARCADIS alone is a valuable tool for intraoperative 3D visualization.[12,17,19] Radiation protection for patient and personnel is another important topic. The radiation of an ARCADIS-based CAS guided drilling procedure is, of course, higher compared with an arthroscopically based drilling. However, the ARCADIS-based CAS procedures produce less radiation than all conventional C-arm based procedures and CT-based CAS.[6]

CONCLUSION

The advantages of this technique are actual intraoperative 3D imaging for the use of navigation without the need for anatomical registration (matching) and an immediate intraoperative control of surgical treatment. The results of this case demonstrate accurately navigated drilling with the described system. The accuracy was confirmed with immediate intraoperative 3D imaging. Our results indicate that ARCADIS-based CAS guided retrograde drilling is a good alternative to arthroscopically guided or 2D-based CAS guided drilling of OCD lesions of the talus.

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