Accuracy analysis of Iso-C\textsuperscript{3D} versus fluoroscopy-based navigated retrograde drilling of osteochondral lesions

A PILOT STUDY

The aim of this pilot study was to evaluate the accuracy of two different methods of navigated retrograde drilling of talar lesions. Artificial osteochondral talar lesions were created in 14 cadaver lower limbs. Two methods of navigated drilling were evaluated by one examiner. Navigated Iso-C\textsuperscript{3D} was used in seven cadavers and 2D fluoroscopy-based navigation in the remaining seven. Of 14 talar lesions, 12 were successfully targeted by navigated drilling. In both cases of inaccurate targeting the 2D fluoroscopy-based navigation was used, missing lesions by 3 mm and 5 mm, respectively. The mean radiation time was increased using Iso-C\textsuperscript{3D} navigation (23 s; 22 to 24) compared with 2D fluoroscopy-based navigation (14 s, 11 to 17).

Osteochondral lesions of the talus are described as a detachment of a cartilage fragment with or without involvement of the subchondral bone.\textsuperscript{1} The classification described by Berndt and Harty\textsuperscript{1} is widely accepted and is based on radiographs. In stage I, a relatively small area of the subchondral bone is compressed. In stage II, the osteochondral fragment is partially detached. In stage III the fragment is completely detached but not displaced, and in stage IV the fragment is detached and displaced.

The aim of surgical treatment is revascularisation of the defect.\textsuperscript{2,3} This can be done via either an antegrade or a retrograde approach. Antegrade drilling and/or curettage with direct visualisation of the defect can be performed arthroscopically or by open surgery. Anterolateral lesions are often accessible by arthroscopy. However, posteromedial lesions are technically challenging arthroscopically, particularly in patients with stiff ankles.\textsuperscript{4,5} These lesions often require a medial malleolar osteotomy, which has been associated with inferior results.\textsuperscript{4,7} The cartilage is violated by all antegrade procedures, whereas it is left intact by retrograde drilling. However, it is difficult to target the lesion by retrograde drilling.

Computed tomography (CT) guidance is not commonly used for precise retrograde drilling of talar osteochondritis dissecans; CT imaging allows precise analysis of the lesion, but C-arm assistance is more limited owing to difficulty in identifying the lesion on fluoroscopic images.\textsuperscript{7,9} In this situation, 3D navigation can be useful.

CT, fluoroscopic and 3D-based navigated drilling techniques for osteochondritis dissecans lesions have been described previously, including detailed evaluation of the different techniques.\textsuperscript{10,11} Successful outcomes have been reported for all three imaging modalities. However, we know of no report that compares the accuracy of these techniques. Three-dimensional image-based navigation systems have been most commonly recommended,\textsuperscript{10,11} but no comparison of the use of 2D and 3D imaging modalities for osteochondritis dissecans lesions has been made. We therefore conducted a pilot study to identify the most accurate imaging modality for navigated drilling procedures in osteochondritis dissecans lesions.

The aim of the study was to evaluate the accuracy and radiation exposure of Iso-C\textsuperscript{3D} (Siemens, Erlangen, Germany) and 2D fluoroscopy-based navigation for retrograde drilling of osteochondral lesions of the talus.

Materials and Methods

A posteromedial osteochondral-like lesion of the talus was created in 14 anatomical specimens via a medial malleolar osteotomy (Fig. 1). The Surgigate navigation system (Praxim-Medivision, Grenoble, France) was used for navigated drilling of the lesion. The accuracy of this system and the camera have been previously described.\textsuperscript{12} The foot was placed on a carbon fibre table and the rigid body placed at the talar neck using a newly developed fixation technique based on an angle stable screw. This
minimises the artefacts that might arise with the Iso-C\textsuperscript{3D} technique. The screw consists of a cone inlay within a deployable anchor system. The screw inlay is precisely guided by a sleeve and fixed at the end by its head. By turning the cap, the cone is drawn into the inlay and retractable tines are deployed to anchor the screw and provide rotational stability (Fig. 2). In all cases the screw was fixed to the bony cortex of the anterior talar process under fluoroscopic control after pre-drilling a 4 mm hole (Fig. 3). After the navigated procedure, the screw was easily removed by unwinding the cap and disengaging the tines of the anchor system.

\textbf{Iso-C\textsuperscript{3D} navigation.} The navigation system was connected to the Iso-C\textsuperscript{3D} (Siremobil, Siemens, Erlangen, Germany), which rotates 190° around the operative field, and must be positioned isocentrically to the region of interest, in both anteroposterior (AP) and lateral projections. Iso-C\textsuperscript{3D} imaging is then performed and multiplanar reconstructions
generated during one automated rotating scanning procedure. After the scans were performed the images were transferred to the navigation system. A trajectory was planned for guidance of the navigated drill guide based on these reconstructions (Fig. 4).

2D fluoroscopy-based navigation. For this part of the study the Iso-C 3D was used exclusively in the 2D mode. After positioning the C-arm using the laser and control images, AP, lateral and oblique views were taken and imported into the navigation system. A trajectory for the drilling was planned using these images (Fig. 5).

Seven retrograde drillings were performed using both 3D and 2D navigation. The drillings were performed with a 3.5 mm drill bit, a drill sleeve and an electric drill (Power Drive, Synthes, Bochum, Germany) (Fig. 6). During the procedure the examiner (MC) was blinded to the anatomy. The endpoint was perforation of the contralateral cortex so as to visualise the drill bit in relation to the target via the malleolar osteotomy (Fig. 1).

Analysis. The image quality was assessed by the examiner using a visual analogue scale (VAS) from 0 (poor image quality) to 10 (excellent image quality), based on the images provided on the monitor screen. The position of the drilling channel was analysed by a post-operative ISO-C3D scan, a CT scan, and direct inspection of the drill bit. The total radiation time was measured for both methods of navigation. Student’s t-test (p < 0.05) was used to compare the groups.

Results

The image quality was rated 9.5 (8 to 10) with Iso-C3D navigation and 6.3 (3 to 9) with 2D fluoroscopy-based navigation (p > 0.05). The mean radiation time of 23 seconds (22 to 24) using Iso-C3D navigation was significantly increased compared with 2D fluoroscopy-based navigation of 14 seconds (11 to 17) (p < 0.05). In total, 12 of 14 lesions were successfully targeted; all seven using the Iso-C3D and five of seven using 2D fluoroscopy-based navigation. One lesion was missed by 3 mm, and one by 5 mm. No loosening of the reference base on the fixation pin was observed.

Discussion

Accurate targeting of osteochondral lesions of the talus by retrograde drilling is difficult, and failure rates as high as 20% have been reported.5,13-15 It is technically challenging owing to the difficulty of identifying the lesion on 2D images and of matching the arthroscopic view with the trajectory of the drill.16 Three-dimensional visualisation of the anatomy facilitates identification and targeting of the lesion. The efficacy of 3D visualisation was reflected in the accuracy achieved in the navigated Iso-C3D group. Another navigated 3D method for targeting talar lesions has been described by Bale et al17 and is based on pre-operative CT datasets. The authors solved the problem of registering the pre-operative images with the intra-operative situation by using a removable and sterilisable cast.10,17 However, this is a complicated procedure and may be unreliable if the shape or the position of the cast changes in relation to the ankle.

The quality of ISO-C3D images is inferior to that of standard CT images. However, the evaluation of fracture lines, the presence of intra-articular hardware and the quality of fracture reduction has been shown to be comparable when using ISO-C3D and CT images.12,18,19 For the detection of
osteochondral lesions, the quality is close to that of CT imaging (Fig. 4). In all experiments the lesion was assessed in multiple planes and the trajectory planned without problems. Specific problems can arise from intra-osseous metallic fixation of the rigid body causing radiological artefacts. This was solved by the development of a new fixation pin (Figs 2 and 3)\textsuperscript{3D} designed for rotational stability, and to cause minimal artefact.

The overall precision of both the fluoroscopy and 3D-based navigated drillings was impressive. However, the Iso-C\textsuperscript{3D} technique demonstrated significantly better image quality than the fluoroscopic technique. We feel it provides more refined control of the trajectory, but this comes at the expense of increased radiation exposure. This was a pilot study which did not have sufficient power to establish the improved precision of a 3D-based navigation system compared with a fluoroscopic one, although a trend towards more accurate targeting was demonstrated with the 3D navigation system. We feel that this is due to more refined visualisation of the lesion, rather than inherent differences in the accuracy of the two systems.

These novel navigation techniques have been applied to osteochondritis dissecans lesions in a limited number of specialised clinics and have not been systematically investigated. Our pilot study therefore provides an insight into these techniques to support future clinical and cadaver studies. Further laboratory studies may be necessary to investigate the ability of these techniques to target lesions successfully in different areas around the talar dome, and to distinguish lesions with different radiological appearances.

Our results demonstrate that the advantages of Iso-C\textsuperscript{3D} navigation must be weighed against the increased radiation time, compared with 2D navigation. However, during the scanning procedure staff may leave the operating theatre and the person performing the scan may be shielded from the control area, which measures 3.5 m. A second Iso-C\textsuperscript{3D} scan was not required for targeting the lesion in these cadaver cases. However, a second scan may be useful for intra-operative validation of the position of the drill bit in relation to the lesion. The additional costs over conventional techniques are a concern. Although technically feasible, it is not clear that the high accuracy of the navigated Iso-C\textsuperscript{3D} system will result in improved clinical results compared with conventional techniques. Further studies are needed to assess the clinical value of this tool.

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References