Image-guided osteochondral autologous autografting of the ankle

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Introduction: Osteochondral defects in the ankle are often associated with a traumatic injury such as a severe ankle sprain. A defect can either heal and remain asymptomatic or progress to deep ankle pain on weight bearing and formation of subchondral bone cysts. In the latter case, surgical treatment is often necessary, such as arthroscopic debridement and microfracture. For cases where these treatments fail, and for very large defects, osteochondral autologous autograft (also called mosaic arthroplasty) is the preferred treatment method. During this procedure, small osteochondral plugs are retrieved from the periphery of the femoral-patellar joint and transplanted into the damaged regions of the talus. For long-term success of this procedure, the transplanted plugs must accurately reconstruct the curvature of the articular surface. The different curvatures between femoral-patella joint and the dome of the talus makes the reconstruction difficult and requires substantial experience.

We present a clinical case in which computer-assisted planning and navigation was used to aid the surgeon in performing an ankle mosaic arthroplasty.

Materials: A 37 year old female patient with a long history of ankle problems was seen in clinic after a repeat inversion sprain with sharp and aching pains in her right ankle with associated swelling. A magnetic resonance imaging (MRI) scan of the ankle revealed an osteochondral injury of the dome of the talus with an approximate size of 20mm x 9mm. As a treatment option a mosaic arthroplasty with bone and cartilage transplanted from the right knee joint was chosen.

Prior to the surgery, a CT scan of the ankle was performed with an intra-articular injection of a contrast medium, in order that the cartilage surface also be visible. This CT arthrogram was obtained in helical mode, with a slice thickness from 1.25 mm at 120 kpV. A CT scan of the right knee using the same slice thickness and kpV was also obtained; no contrast medium was used for the knee.

3D bone models for the knee, the ankle, and the ankle cartilage were created using the commercial available software package Mimics (Materialise, Leuven, Belgium). Due to the contrast medium in the ankle at the time of the scan, the bone and cartilage model contained the osteochrondal defect. To estimate the cartilage layer in the knee, we identified the grafting areas and created a surface 2mm offset from the bone surface.

The mosaic arthroplasty was planned with our in-house custom-made software. The 3D models were loaded into the software and displayed to the user. The operator, together with the surgeon, created a surgical plan consisting of a set of three osteochondral grafts (“plugs”) positioned over the defect site. The 3D position and orientation of each plug, as well as its shape (diameter, height, and surface slope), were chosen to best reconstruct the desired articular surface at the defect site (Figure 1a).

For each plug, a harvest location in the knee was chosen to best match the shape of the plug. The plugs could be rotated axially so that the sloped surface at the harvest site could be made to match the sloped surface at the defect site. The operator validated the surgical plan by superimposing the plugs on the 3D models (Figure 1a).
Intraoperatively, a Certus tracker (Northern Digital, Waterloo, Canada) was installed in the operating theatre and tracking sensors were rigidly attached to the femur, talus, and conventional harvest chisels and drill guides.

For the intraoperative registration and guidance the bone and cartilage models for femur as well as for the talus were combined to one 3D model for each anatomy.

Registrations were made between the patient’s femur and the 3D femur model and between the talus and the 3D talus model using a combined pair-point, and surface matching algorithm.

For each of the three planned plugs the following procedure was performed:

Using a visual and numerical feedback from a custom-made computer-guidance system, the surgeon positioned and oriented the tracked recipient chisel over the planned recipient site at the talus. The surgeon then drove the chisel into the cartilage and bone until the planned depth was reached. After thus preparing the recipient site, an osteochondral plug was harvested from the knee. The surgeon aligned the tracked harvesting chisel over the planned harvest spot using the guidance software. In addition, the surgeon rotated the harvest chisel around its axis until a calibrated “up” position of the tool aligned with a visual rotation mark of the virtual plug on the computer guidance display. Then the surgeon drove the chisel into cartilage and bone until the planned depth and harvested the plug.

The harvest chisel was then aligned over the prepared recipient site and the surgeon used the guidance system to rotate the harvest chisel around its axis to the planned axial orientation. The plug was then pushed into the recipient hole and the harvest chisel removed.

All three plugs were harvested and delivered in this manner (Figure 1b).

**Results:** Eight weeks postoperatively the patient was walking without any aid. She had a dorsiflexion of 0-20° and a plantar-flexion of 0-35°. She still had some mild tenderness in the medial and lateral aspects of the ankle.

At 6 months postoperative she had a significant improvement in her passive range of motion from 0-15° dorsi-flexion and 0-60° plantar-flexion, compared to her uninjured ankle of 0-15° dorsi-flexion and 0-80° plantar-flexion. The inversion and eversion of the ankle were normal and X-ray evaluation showed good and complete integration of the osteochondral plugs.

**Discussion:** A virtual preoperative planning tool help to solve the complex geometrical problem of reconstructing the articular cartilage surface of the talus using multiple autologous osteochondral plugs from the knee. The intraoperative optoelectronic guidance allowed the surgeon to transfer this plan into the intraoperative situation.

So far, the postoperative outcome is very encouraging: The patient is making good progress and is satisfied with the outcome of the surgery. A postoperative MRI will soon be obtained to determine how well the cartilage surface was reconstructed.