Computer-assisted surgery for allograft shaping in hemi-cortical resection: A technical note involving 4 cases

JG Gerbers, PMA Van Ooijen, PC Jutte

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Introduction

Hemicortical resection was first described by Campanacci et al (1982) (1). Several studies support the technique as a safe alternative to larger segmental resections for low-grade chondrosarcoma (Deijkers et al. 2002), parosteal osteosarcoma (Lewis et al. 2000, Pezzillo et al. 2008) and adamantinoma (Agarwal et al. 2007) (2-5). However there have been several complications reported with this resection and reconstruction, the most important being fractures of the host bone, inadequate margins, and infection.

The resections and reconstructions are usually done without objective 3-D measurements. Computer-assisted surgery (CAS) offers objective measurements in 3D with high accuracy. It can be used to produce an exact copy of the resected part of the host bone by using the same resection planes in both tumour and allograft resection. In this technical note we describe the technique, report results and identify shortcomings and possibilities.

Surgical technique

We used a fresh frozen donor tibia with similar dimensions as the host tibia. A preoperative CT-scan was performed of both the patient and the donor bone. These scans were imported in the CAS system (Stryker, Mahwah, NY. Orthomap software) and manually matched to find the optimum overlay. Special care was given to match the cortices of the host and donor bone. The resection was planned with both resection planes and annotation points. The planned resection planes (Figure 1) from the CAS setup of the host bone are now also usable in the allograft dataset because the two datasets are linked and matched in the CAS system.

Normal CAS setup was performed using a patient tracker placed on the tibia. A system calculated deviation, between the CT and spatial data, of less than 1.0 mm was accepted as in our normal image-based set-up. The pointer tool was then used to identify and mark the edges and entry points of the planned trapezoid or wedge-like shape. The excision planes were marked with a pen and checked with the pointer tool for accuracy. The corners of the resection shape were marked with annotation points (as special interest points) as extra feedback. We used an oscillating bone saw to perform the pre-planned trapezoid or wedge shaped resection. Angulation of the saw was checked at intervals using the pointer tool. Resection planes were checked again for margin after resection. The exact same procedure was followed in the allograft bone (Figure 2). 2 screws were used for fixation of the grafts.

Patients

4 patients were selected for hemicortical resection using CAS. All had a diagnosis of adamantinoma, reported by a specialized musculoskeletal pathologist. Mean
patient age was 22 (8-54) years. In 3 of the 4 cases 50 percent or more of the bone circumference was involved by the tumour. The length of the resection and allograft was on average 7.5 (6.0 – 9.0) centimetres. The surgical margin was marginal in three patients and wide in 1, depending on adamantinoma subtype.

All grafts were reported by the radiologist as well aligned and with good bone contact. Post-operative and follow-up radiographs of the first patient are presented in figure 3. All patients are currently able to walk unassisted and function is excellent. All are disease-free. There have been no complications.

Full allograft integration is reported in three patients. In the fourth patient progressive consolidation and proximal incorporation is reported at the three month follow-up. Mean time until full integration, measured by the fading of the boundary line, was 6 months (5 – 8 months).

A 1 day post-operative CT scan, 1.0 mm slice thickness, of the fourth patient was analysed using advanced visualization software (iNtution, TeraRecon and Photoshop CS5, Adobe). It showed an average gap of 0.9 (0 – 5.4) mm. In these 60 slices, 76 gap measurements of 120 were below 1.0 mm. This was with 2 measurements per slice, the lateral and medial gap between host and donor bone. A gap of more than 5 mm was only measured once.
Discussion

Deijkers (2002) described 22 patients with low-grade malignant bone tumours who underwent hemicortical resections (2). A fracture of the remaining hemicortex occurred in 6 patients: in 3 patients during the operation and in 3 others shortly afterwards. The authors speculate that with a way to tailor the allograft precisely to match the host bone defect, i.e. a larger graft-bone contact area, fewer complications like fractures could occur.

Our preliminary results indicate CAS makes it is possible to both resect and reconstruct more precisely. This may lead to less intraoperative and postoperative fractures due to a better allograft fit. Furthermore, earlier integration can be expected if the gap between host bone and allograft is smaller.

The proximal resection plane in figure 4 shows, especially for the medial cortex, an increasingly bigger gap. We think this is due to an angulation error of the oscillating saw. Due to increasing distance from the entry point the error accumulates. The correction to the planned angle can be seen in the CT scan as there is a small fragment of bone

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Figure 3: Radiographic series of the first patient. A) OFD-Like AD lesion in situ. B) Immediately post-operative. Both the graft and the host resection planes are smooth and in close proximity. The distal point of the host bone has a small defect created most probably by the saw blade’s vibrations. The remaining gap is filled with Vitoss (Orthovita Inc, Malvern, PA). C) Progressive ingrowth after 5 months. Cortical hypertrophy is clearly visible. D) Full integration and almost entirely faded boundary line at 16 months.
Figure 4 (left): Graph of the post-operative CT scan of the fourth patient. Average gap was 0.9 mm (range 0 mm – 5.4 mm). The sharp increase of the medial gap is due to an angulation error during resection.

Figure 5 (right): 3D rendered images of the fourth patient. Made with iNtution (TeraRecon). The allograft is auto-segmented and coloured green. Medial view shows the defect caused by an angulation misalignment in the last stage of the proximal resection plane. A) Medial view. Two distinct resection cuts are visible B) Anterior-posterior view. C) Lateral view.
between the too wide resection plane and the correct one (Figure 5B). We think that this finding supports the need of a navigated means of resection, as the system can check the angulation of the saw at any point of the resection.

We tried to attach a tracker to a bone saw and use it with navigation in the first procedure, to excise the tumour and cut the graft, but it proved inaccurate. The tracker was attached to the saw and calibrated in a universal calibration tool but the blade was too flexible to calibrate reliably.

Alternatives can be pre-planned saw blocks for both the patient and allograft bone. CAS has the advantage that the resection planes can be adjusted during surgery and there is no placement inaccuracy. Another alternative is the pre-fabrication by 3d printing of a filler material. Accurate resection has to be performed for the filler to fit, and we feel navigation is again required. Furthermore a non-biological solution is more likely to fail in the long run.

The CAS system makes the creation of the allograft easier. The technique can be applied to any bone tumour eligible for hemicortical resection but also other defects requiring bony reconstructions.
References


