Enhancing precision and accuracy in bone tumour treatment; an experimental comparison of freehand, computer assistance (CAS) and a novel universal CAS saw guide.

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Background

Better knowledge of tumour biology, multimodal treatment and advances in imaging and surgical technology have enabled a trend in orthopaedic oncology to save more healthy tissue while safely removing the tumour. This enabled that some low-malignant lesions can be treated without resecting the full diameter of the bone. Hemi-cortical (or multiplanar) bone tumour resections and reconstructions are however demanding procedures. The technique depends on high surgical accuracy to achieve an oncological safe resection and it is associated with complications such as fractures.

Recent developments show that Computer Assisted Surgery (CAS) can be used to simplify the creation of highly accurate allograft by exactly duplicating the used tumour resection paths. However CAS only provides intra-operative feedback as it just helps in orientation, the resection is still performed free-handed. This introduces a new universal tool, designed to offer objective resection guidance during surgery. Accuracy and precision of the resection and reconstruction procedure was compared between three surgical techniques, freehand, CAS and the novel universal CAS guide, in a distal femoral cadaver bone-tumour model.

Study design

An experimental study was performed. A distal femoral cadaver bone-tumour model was chosen to accurately simulate a real procedure. Six Thiel-embalmed cadavers were used. The surgical plan was to resect a virtual tumour in the one femur and to reconstruct the defect with a graft resected from a matching femur. Pre-operative and post-operative imaging, together with surgical planning software, provided both a surgical objective and offered high-resolution measurements. A high grade sarcoma was simulated in each of the three tumour resection specimens, on the anterior side of the distal femur. Each resection was planned as 80 mm long and to a maximum depth of 70% of the diameter of the bone. Tumour resection margins (or the accuracy of the resection) were checked using 3D measurement of the achieved resection planes against the tumour edge planes in a 4 by 4 mm grid pattern. Overall resection margin was calculated using the tumour, planned resection and achieved resection volumes, measured by manual segmentation. Reconstruction accuracy was measured on coronal slices by measuring the length of the gap between the centres of the cortices of the graft and host bone every 2 mm.

Results

Three procedures had intra-lesional resections, the two freehand procedures and one of the CAS procedures Point-measured resection accuracy was lowest in the freehand procedures (6.1 and 4.0 mm), good in CAS (3.9 and 3.2 mm) and highest in the two CAS guide procedures (3.0 and 1.2 mm). Achieved graft volume compared to the planned graft volume, was lowest in the freehand group (45% and 68%) and highest in the CAS-guide procedures (76% and 99%). The mean reconstruction gap was largest in the fluoroscopy cases (2.3 mm, 1.9 mm), with the lowest in the CAS (1.5 mm, 1.2 mm) and CAS guide procedures (1.3 mm, 1.1 mm). Plane smoothness (precision) was lowest in the freehand procedures and highest in the CAS-guide procedures.

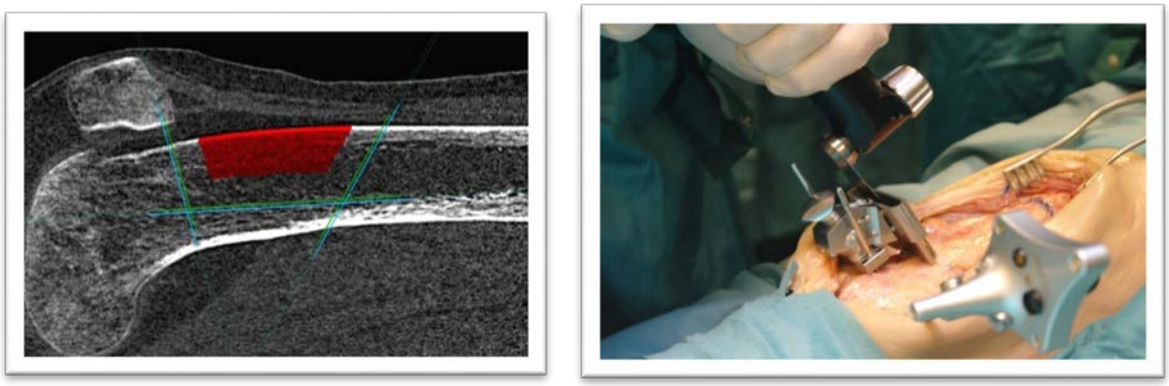
Discussion

The result of this experiment underlines the observation that these types of multi-planar resections are very demanding. None of the six resections, even with imaging support, achieved the exact required margin. All resections resulted in cuts that were too conservative, i.e. cuts with less than 10 mm margin

surrounding the tumour. Three procedures (2 fluoroscopy cases, 1 CAS) even had a local error of over 10 mm, resulting in intra-lesional resections. Possible CAS matching errors resulted in the intralesional resection. While the optimum result was not achieved, a clear trend in resection and reconstruction accuracy is visible in the results. Achieved resection accuracy for CAS was comparable to literature. CAS-guides did slightly better.

Conclusion

CAS and especially the CAS-guide procedures have demonstrated higher accuracy resections and reconstructions than freehand. Compared to freehand there was improvement in clinical results, measured margin, plane placement, gap and volume of en-bloc tumour and graft. The CAS guide is a tool that can be used to enhance the actually achieved accuracy closer to the real accuracy of the CAS system. This enhanced accuracy and precision potentially increases functional outcome, oncological outcome and complication rates. The CAS guide can be applied to more types of procedures. With a modular design it can assist in pelvic resections, wedge osteotomies or any other type of resection. The addition of the CAS guide made it possible to find the exact plane as well as actually achieve the exact planned cuts. The design will be released under an open source license on publication of the paper.



Figures showing the planning of a hemi-cortical resection L, and the execution using the universal CAS guide R.