Musculoskeletal Tumor Society Information Statement

3D-Printed Patient-Specific Instruments in Bone Sarcoma Surgery

Novel Practice Assessment

In these occasional Novel Practice Assessments, the MSTS Guidelines and Evidence-Based Medicine Committee will assess the evidence underlying novel diagnostics and therapies entering clinical practice in musculoskeletal oncology. The goal is to assist MSTS members make more informed decisions for their patients. As evidence is expected to change rapidly, articles will be rewritten or removed after one year.

Author: Matthew T. Wallace, MD, MBA. MedStar Georgetown Cancer Institute

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Summary

Pros:

1. Precision bony cuts to facilitate negative margin surgery for bone sarcomas
2. Can be used concurrently for matched allograft reconstruction or 3D-printed custom implants
3. Facilitates surgery for complex anatomy such as pelvis/spine
4. Can provide precision shaping of intercalary reconstructions of long bones

Cons:

1. Additional expense
2. Time for fabrication must be planned to avoid risk of delaying treatment

Background

Limb-salvage, margin-negative surgery is the mainstay of treatment for sarcomas of bone. The musculoskeletal oncology surgeon is tasked with optimizing the long-term functional outcomes of the patient while maintaining appropriate oncologic outcomes. Free-hand resections of bone tumors are associated with discrepancies between planned resection and specimen lengths up to 20 mm, with an unplanned intralesional margin in 8% of cases.

What is new?

Recent advances in tumor imaging and 3D technologies may permit more accurate, tighter resections around bone sarcomas that facilitate limb and joint salvage and/or reconstruction. 3D technology may be used to create surgical models that help visualize surgery and measure resections preoperatively, and intraoperative 3D navigation has been used with CT-based optical navigation systems to localize and direct instruments in real time. Currently, patient-specific instruments (PSI) and implants can be designed and fabricated, which are then applied onto or inserted into the bone to precisely template and complete

bony cuts, size-match allografts, or provide custom replacements for reconstruction. However, these advances come with both time and monetary expenses. The clinical benefits of PSI are still under scrutiny as emerging practices.

Methods

A search of PubMed online database was performed on 9/27/2022. Search terms included "3D technology," "3D navigation," "3D Guide," "3D Visual," "3D printing," "sarcoma," "excision margin," "resection margin," "surgical margin," "margin status," "negative," "recurrence," "neoplasm," "recurrence, local," "postoperative complications," and "intraoperative complications." Limits were placed to exclude non-English manuscripts and case reports.

A total of 24 citations were identified. 11 citations were excluded as technical papers or those unrelated to orthopaedic oncology. 7 citations were excluded for not utilizing PSI, such as 3D models or intraoperative navigation only. 6 citations were included and are summarized below.

Results

Only 1 study provided a case-control series comparing PSI resection to manual free-hand resections. The other 5 are cohort studies that evaluated between 6 and 31 patients. There was only 1 reported intralesional osteotomy with PSI (1%). There were 2 planned R1 margins adjacent to critical structures (2%), and all other osteotomy margins were negative (97%). Soft tissue margins were infrequently reported but none were reported as positive. The difference between the planned resection and the measured specimen was low, generally 0-3 mm. These differences may be partially accounted for by the thickness of the surgical saw blade. Complications rates are generally attributed to the procedure and method of reconstruction rather than the use of PSI, which was not found to be consistently associated with differences in operative time or blood loss.

Future Directions

There is much information needed to evaluate the use of patient-specific instrumentation. PSI may be of benefit in obtaining negative margins in bone sarcoma surgery, but it remains to be seen if PSI-matched allografts or custom implants made with solid free-form fabrication or additive manufacturing demonstrate better long-term functional outcomes.

Citations

Park JW, Kang HG, Kim JH, Kim HS. The application of 3D-printing technology in pelvic bone tumor surgery. *J. Orthop. Sci*. 2021 (26): 276-83.

-12 patients
-9 Custom implants
-All margins negative, 1 local recurrence
-Mean difference between planned cut and specimen measurement 1.8 mm (range 0-3 mm)
-Fabrication times for guides and implants range 6-22 days

Evrard R, Schubert T, Paul L, Dcoquier PL. Resection margins obtained with patient-specific instruments for resecting primary pelvic bone sarcomas: A case-control study. *Orthop.& Traumatol. Surg. & Res.* 2019 (150):781-7.

-9 patient case vs. 19 patient historical control study
-7 Allografts in PSI group
-PSI bony margins R0 except 1 planned R1 margin to salvage S1 nerve root, compared to 6 positive margins in control group (p=0.47)
-No local recurrences in PSI group, compared to 7 in control group (p=0.03)
-2 Infections, 1 case AVN femoral head
-No difference in operative time

Dong C, Beglinger I, Krieg AH. Personalized 3D-printed guide in malignant bone tumor resection and following reconstruction – 17 cases in pelvic and extremities. *Surgical Oncol.* 2022 (42):101733

-17 patients
-12 allografts, 5 custom implants
-1 positive margin
-91.7% rate of allograft junction healing
-23.5% wound complications, 17.6% infection.
-Maximum difference between planned cut and specimen measurement 8.35 mm

Evrard R, Schubert T, Paul L, Docquier PL: Quality of resection margin with patient specific instrument for bone tumor resection. *J. Bone. Oncol.* 2022 (34):100434.

-31 patients
-All margins negative
-Mean margin of difference between planned cut and specimen measurement 0.4 mm, maximum 5 mm

Benady A, Meyer JS, et.al. Intercalary and geographic lower limb tumor resections with the use of 3D printed patient specific instruments – when less is more. *J. Orthop.* 2022 (32): 36-42.

-17 patients with long bone intercalary resections
-8 allografts, 7 vascularized fibulae, 2 custom implants.
-1 planned R1 margin
-2 wound infections, 1 vascular occlusion, 3 graft nonunions, 1 traumatic fracture, 1 local recurrence

Gasparr MA, Gusho CA, Obioha OA,Colman MW, Gitelis S, Blank AT. 3D-printed cutting guides for resection of long bone sarcoma and intercalary allograft reconstruction. *Orthopedics*. 2022 (45): e35-41.

-6 patients with long bone intercalary resections
-All negative margins
-25% graft nonuions, 33.3% complication rate overall