3D-Printed Patient-Specific Cutting Guides versus Freehand Resection for Internal Hemipelvectomy: Clinical and Oncologic Outcomes

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INTRODUCTION:

While wide margin resection via internal hemipelvectomy remains the cornerstone of limb-salvage curative-intent treatment for pelvic sarcomas, the complex three-dimensional (3D) anatomy around the posterior pelvis and sacroiliac (SI) joint and the proximity to critical neurovascular structures, internal hemipelvectomy is among the most difficult and technical procedures in musculoskeletal oncology. Advancements in 3D technology have led to patient-specific cutting guides that may better achieve negative margins through more accurate and precise cuts, reduce surgical time, help avoid complications, and prove more cost-effective than other modalities. However, despite its promise, there is no consensus supporting their routine use in internal hemipelvectomy. This study sought to control-match a cohort of patients undergoing pelvic and sacral resection for osseous sarcoma with the freehand method to those in whom a 3D-printed cutting guide was used. It evaluated and assessed functional and oncologic outcomes of patients in either group, while also comparing the peri-operative complication profiles between each of the two groups in an attempt to determine the feasibility of 3D-printed patient-specific cutting guides for use in orthopedic oncology.

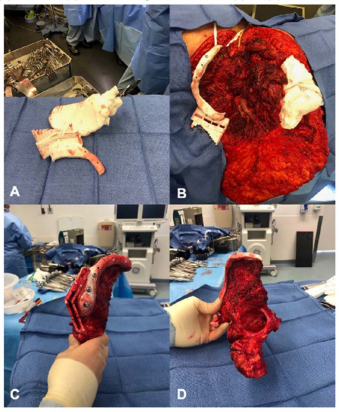
METHODS: Institutional Review Board approval was obtained to retrospectively review a prospectively maintained surgical database over a consecutive 20-year period. Inclusion criteria were patients with primary or secondary bone sarcoma of the pelvis (with or without sacral invasion) who underwent resection using a 3D-printed, patient-specific cutting guide or freehand technique. A cohort of patients who underwent internal hemipelvectomy using the freehand technique were then control-matched using the hemipelvectomy resection type. Secondary matching criteria included the primary histopathological diagnosis, tumor size, and individual surgeon's experience with internal hemipelvectomy. This process yielded a cohort of 22 patients who underwent hemipelvectomy with the freehand method for comparison. For comparison of continuous variables between the freehand and 3D-printed cutting guide groups, a two-sample independent *t*-test was utilized. For comparison of categorical variables between each group, a Pearson Chi square test or Fisher's Exact test was used where applicable. The threshold for statistical significance was set to $p < 0.05$.

RESULTS: Twenty-two patients treated with freehand resection were matched to five using a 3D-printed cutting guide. Negative margins were recorded in 50% (n = 11/22) of freehand patients and in 100% (n = 5/5) of the 3D-printed group (p = .040). Local recurrence was more frequent in the freehand group (55.0% vs 0%; p = .027), as was distant metastasis (68.4% vs 0*%; P* = .006). The reoperation rate was significantly higher among freehand patients (*P* = .040), with 50% (n = 11/22) undergoing at least one procedure compared to no 3D-printed cutting guide patients. There was a significantly greater rate of massive blood loss in patients treated with freehand technique (76.2% vs 20%, respectively, *P* = .018) Reconstruction was performed at even rates across cohorts (*P* = .925), with no differences in the construct used.

DISCUSSION AND CONCLUSION:

In this study, despite the small sample size, we found that 3D-printed guides facilitate more accurate resections. Given the shorter follow-up in the guide group, it is difficult to draw conclusions regarding longer-term oncologic outcomes. Nevertheless, we believe this technique offers advantages over the freehand surgical technique.

Figure 1. Intraoperative images from the case of a 69-year-old woman who underwent a combined Type I/II/III/IV resection for grade 2 chondrosarcoma affecting the right hemipelvis. Shown is the custom 3D-printed cutting guide (A) before and (B) after mounting on the iliac crest. (C) and (D) demonstrate the resected tumor.



	Freehand	3D Cutting Guide	*p*
	n = 22	n = 5	
General Surgery Involvement	9/22 (40.9%)	4/5 (80%)	.114
Resection Type			
Type I	2/22 (9.1%)	0/5 (0%)	.484
Type I/II	3/22 (13.6%)	1/5 (20%)	.718
Type I/II/III	4/22 (18.2%)	0/5 (0%)	.302
Type I/II/III/IV	3/22 (13.6%)	1/5 (20%)	.718
Type I/IV	5/22 (22.7%)	3/5 (60%)	.099
Type I/II/IV	1/22 (4.5%)	0/5 (0%)	.627
Type IV	4/22 (18.2%)	0/5 (0%)	.302
Reconstruction	18/22 (81.8%)	4/5 (80%)	.925
Iliofemoral Arthrodesis	5/18 (27.8%)	0/4 (0%)	.230
Allograft	7/18 (38.9%)	2/4 (50%)	.683
Hardware Fixation	3/18 (16.7%)	1/4 (25%)	.696
Acetabuloplasty	3/18 (16.7%)	1/4 (25%)	.696
Internal Iliac Arteries Sacrificed	7/22 (31.8%)	1/5 (20%)	.601
Margin Status			
Negative	11/22 (50%)	5/5 (100%)	**.040**
Marginal	7/22 (31.8%)	0/5 (0%)	.143
Positive	4/22 (18.2%)	0/5 (0%)	.302
Closest Margin (mm) †	7.1 ± 3.8	8.0 ± 2.9	.694
Tumor Size (cm) †	10.6 ± 4.9	9.3 ± 2.0	.572
Operative Time (min) †	453.1 ± 173.5	415.8 ± 203.5	.677
Massive Blood Loss (> 2L)	16/21 (76.2%)	1/5 (20%)	**.018**

Bold p-value denotes significant departure from expected counts with alpha set to 0.05; † Mean ± Standard Deviation (SD)