Research Article

Outcomes After Abductor Reattachment to Proximal Femur Endoprosthesis After Tumor Resection

Maroun Rizkallah, MD, MSc
Karla Teresa Araneta, MD
Ahmed Aoude, MD, MEng
Robert Turcotte, MD

ABSTRACT

Introduction: Resection of the proximal femur raises several challenges including restoration of the abductor mechanism. Few evaluated the outcomes of different techniques of abductor fixation to the proximal femur endoprosthesis.

Methods: A retrospective review of patients who underwent proximal femoral arthroplasty with a minimum follow-up of 12 months was conducted. Patients were divided into two groups: (1) those with preserved greater trochanter (GT) reattached to the implant and (2) those with direct abductor muscle reattachment. Both groups were compared for surgical and functional outcomes. Group 1 patients were subdivided into those who received GT reinsertion using grip and cables and those reattached using sutures.

Results: Fifty-three patients were included with a mean follow-up of 49 months. There were 22 patients with reinserted GT and 31 patients with soft-tissue repair. The endoprosthesis revision rate was comparable between groups ($P = 0.27$); however, the incidence of dislocations was higher in group 2 (0/22 versus 6/31; $P = 0.035$). Trendelenburg gait (77% versus 74%), use of walking aids (68% versus 81%), and abductor muscle strength were comparable between both groups ($P > 0.05$). In group 1, 15 patients had GT reinsertion with grip and cables. Of those, five patients (33%) had cable rupture within 13 months of follow-up. GT displacement reached 12 mm at 12 months of follow-up in patients with grip and cables compared with 26 mm in patients with GT suture reinsertion ($P < 0.05$).

Discussion: Although GT preservation did not improve functional outcomes, it was associated with a lower dislocation rate despite frequent cable failure. Less displacement was observed when GT reattachment used grip and cables.

From the Department of Orthopedic Surgery, McGill University Health Centre, Montreal, Quebec, Canada.

Correspondence to Dr. Rizkallah: Maroun.rizkallah@gmail.com

None of the following authors or any immediate family member has received anything of value from or has stock or stock options held in a commercial company or institution related directly or indirectly to the subject of this article: Rizkallah, Araneta, Aoude, and Turcotte.

J Am Acad Orthop Surg 2023;31:34-40

DOI: 10.5435/JAAOS-D-22-00369

The proximal femur is a common location for primary bone sarcomas and metastases.[1-3] Increased life expectancy, improved quality of life of patients with cancer, and the reliability of endoprosthetic reconstruction have led to a surge in proximal femoral arthroplasties.[2,4-6] Despite availability of modern modular implants, reconstruction after proximal femur resection for tumor raises several challenges.[3,7-9] These include increased risk of infection, instability and recurrent dislocation, periprosthetic fracture, limb-length discrepancy, acetabular wear, and aseptic loosening.[3,7-9] Prognosis of patients with cancer is improving with advances in systemic therapies and thus enhances expectations toward functional restoration and quality of life.[10] Preservation of the abductor muscle function is expected to maximize hip function that otherwise leads to a Trendelenburg gait and hip instability.[11-13] None is known about the optimal method of abduction mechanism reattachment after tumor resection. This is not only because of the complexity and heterogeneity of the cases depending on the extent of the tumor that dictates the resection but also because of the divergent surgeons' preferences based on their convictions and training and on the difficulties to reproduce an anatomical and functional reattachment of tissues to the implant. In some instances, preservation of the greater trochanter (GT) through flip or digastric osteotomies, followed by its reattachment to the porous-coated surface of the prosthesis, might represent an optimal scenario. In other instances, direct reattachment of the abductor tendons to the prosthesis or an attempt at tenodesis to the fascia lata is selected. Sparse data in the literature showed that osseous reattachment yielded similar outcomes when compared with direct reattachment for Trendelenburg gait and need for assistive devices.[14] This study aims to evaluate surgical, radiological, and functional outcomes in patients with osseous reattachment of the GT in proximal femur endoprosthesis after tumor resection and to compare them with similar outcomes in patients with direct\indirect soft-tissue–only reattachment.

Methods

This retrospective study contains data that were prospectively collected in a musculoskeletal oncology tertiary center. It was approved by our institution review board. All patients who received a proximal femur arthroplasty after tumor resection between 2005 and 2021 with a minimum follow-up of 12 months were included. Patients who had a proximal femoral arthroplasty for failed primary arthroplasties without the diagnosis of tumor and those who had associated complex pelvis reconstruction were excluded. Medical records of the included patients were searched for patients' demographics, diagnoses, details of surgical treatment, complications, revision surgeries, preoperative and follow-up Musculoskeletal Tumor Society (MSTS) and Toronto Extremity Salvage Score (TESS) scores, and functional outcomes. GT displacement and cable failure were measured and documented from radiographic images.

Surgical Technique

All patients had bipolar hemiarthroplasties using proximal femur endoprosthesis. All patients had a GMRS prosthesis (Stryker), except for two who had a MUTARS implant (MUTARS; Implantcast GmbH). The articular capsule was preserved and repaired over the femoral head in all patients using the same technique. Abductor mechanism reconstruction was either through GT preservation past a flip/digastric osteotomy with its reattachment to the porous surface of the implant or through soft-tissue repair only. The choice between both techniques was mainly dictated by the extent of the tumor, targeted margins, length of the remaining abductor tendons and existing gap to the implant reattachment site, and surgeon's preferences. When bony reattachment was sought, it was done either through grip and cables or through heavy nonresorbable suture materials (No. 5 Ethibond suture, Ethicon). When only soft-tissue repair was done, it was directly done using heavy nonresorbable sutures (materials [No. 5 Ethibond suture]) passed through the abductor tendons that were brought directly to the surface of the prosthesis. When it was not possible to reach the implant, an indirect soft-tissue repair was made by a tenodesis to tensor fascia lata.[15]

Postoperatively, all patients were allowed to bear weight as tolerated, irrespective of the repair technique. No patients were put into abduction braces nor into spica casts. A walking assistive device was prescribed for 6 weeks to protect the abductor repair. Similarly, active abduction and abduction exercises were restricted for the initial 6 weeks, after which abductor reinforcement was encouraged. All patients had routine physical examination and plain radiographs of the pelvis and femur every 3 months for the first 2 years after surgery, then every 6 months for the next 3 years, and yearly thereafter.

Group Comparison

Included patients were divided into two groups. Patients in group 1 had their GT preserved and reattached to the

prosthesis, whereas patients in group 2 had direct or indirect abductor muscle reattachment using heavy sutures. Both groups were compared for surgical outcomes defined as surgical revision rate and dislocation rate. Functional outcomes between both groups at the last follow-up were compared for the presence of Trendelenburg gait (yes/no), use of walking aids (yes/no), abductor muscle strength (graded zero to 5, tested with patients lying on their side), MSTS, and TESS scores.

Subgroup Analysis

Patients in group 1 were further divided into two subgroups. Patients who had their GT repaired with grip and cables (1A) were compared with those who had their preserved GT repaired with heavy suture (1B). Radiographs of all patients were reviewed. GT displacement compared with initial postoperative radiographs was measured at 3, 6, and 12 months postoperatively for both subgroup patients. The distance from the tip of the preserved GT to the bi-ischiatic line on calibrated A/P pelvis radiographs was used to evaluate the displacement of the GT. Mean GT displacement was then compared between both subgroups. In addition, time to metallic cable rupture in patients with grip-and-cable repair was also recorded.

Statistical Analysis

Descriptive analysis included demographics, tumor characteristics, surgical characteristics, complications, and functional and radiological outcomes. Differences in quantitative variables were tested using an unpaired Student *t*-test. The Mann-Whitney test was used when one of the compared groups had less than 20 individuals. Differences in qualitative variables were tested using the Fisher exact test. Confidence interval for percentages was determined using the Wilson score method. Time to cable rupture was recorded and analyzed using a survival analysis. All analyses were conducted using the R software version 4.0.2 (R Foundation for Statistical Computing).

Results

Descriptive Analysis

Fifty-three patients were included in this study with a mean follow-up of 49 months (12 to 180). There were 22 male (42%) and 31 female (58%) patients, with a mean age of 50.88 years (14 to 75). Thirty patients (57%) had primary bone or soft-tissue sarcoma, whereas 23 patients (43%) had proximal femur metastasis. Thirty-three patients (62.2%) remained alive at the end of follow-up, with an estimated median survival of 156 months. Thirty-nine procedures (73.5%) were primary, whereas the remaining 14 surgeries (26.4%) were secondary to previously failed hemiarthroplasty (five patients) or femoral nailing (nine patients).

Group Comparison

Twenty-two patients (42%) had GT preserved (group 1), and 31 patients (58%) had soft-tissue repair (group 2). No differences were observed between the GT-salvaged group and the soft-tissue–only repair group regarding age, sex, body mass index (BMI), diagnosis, baseline MSTS and TESS scores, and type of surgery or follow-up (Table 1). Infection was recorded in 2 of 22 patients of group 1, whereas there were 3 of 31 patients in group 2. Two patients of group 2 demonstrated disease progression. No revision was needed for cable or grip issues. Therefore, the revision rate was comparable between both groups ($P = 0.27$) (Table 2). The incidence of hip dislocations was higher in patients with soft-tissue–only repair: 0 of 22 in group 1 versus 6 of 31 in group 2 ($P = 0.035$) (Table 2). Two of these six patients sustained recurrent dislocations. Seventeen patients in those with preserved GT (77%) and 23 patients with soft-tissue repair only (74%) exhibited a Trendelenburg gait at their last follow-up ($P = 1$). In group 1, 15 of 22 patients (68%) were using walking assistive devices, compared with 25 of 31 patients in group 2 (81%) ($P = 0.34$) (Table 2). Abductor was graded as two in six patients and three in 16 patients of those with preserved GT (group 1) compared with one in five patients, 2 in 12 patients, and 3 in 14 patients of those in group 2 ($P = 0.06$). At their last follow-up, the MSTS score for patients in group 1 averaged 56.34 compared with 66.62 for patients in group 2 ($P = 0.25$). The TESS score for patients with GT preservation at their last follow-up reached a mean of 78.64, whereas that of patients with soft-tissue repair reached 67.32 ($P = 0.38$).

Subgroup Analysis

In group 1, 15 of the 22 patients (68%) had GT reinsertion with grip and cables (group 1A) (Figure 1) while 7 of the 22 patients (32%) had their GT fixed with heavy sutures (group 1B) (Figure 2) to the endoprosthesis. At a mean follow-up of 27.4 months (12 to 156), 5 of 15 patients (33%) showed cable rupture (Figure 1). The median survival of cables reached 13 months. GT displacement measured on calibrated A/P pelvis radiographs compared with initial postoperative radiographs reached a mean of 2, 3, and 12 mm, respectively, at 3, 6, and

Table 1. Comparison Between Patients of Group 1 and Group 2 for Demographic and Baseline Criteria

Factor	Group 1 (GT Conservation)	Group 2 (Soft-tissue–only Repair)	*P*
Patients	22	31	—
Age	49.4 ± 17.5	51.9 ± 18.7	0.62
Sex (males)	11/22 (50%)	11/31 (35%)	0.39
BMI	25.22 ± 7	25.60 ± 7.9	0.91
Diagnosis (primary sarcoma)	10/22 (45%)	20/31 (64.5%)	0.38
Secondary surgery	7/22 (32%)	7/31 (22.5%)	0.66
Follow-up	34.68	58.93	0.09
Baseline MSTS score	57.3244	51.32	0.52
Baseline TESS score	561.32	58.34	0.72

Table 2. Results of the Comparison Between Patients in Groups 1 and 2 for Surgical and Functional Outcomes

Factor	Group 1 (22 Patients)	Group 2 (31 Patients)	*P*
Surgical revision	2 (9%)	7 (22.5%)	0.27
Hip dislocation events	0 (0%)	6 (19%)	0.035
Trendelenburg gait	17 (77%)	23 (74%)	1
Walking assistive device	15 (68%)	25 (81%)	0.34
MSTS score	56.34	65.62	0.25
TESS score	78.64	67.32	0.38

12 months of follow-up in group 1A patients compared with 12, 24, and 26 mm, respectively, at the same follow-up intervals in group 1B patients ($P < 0.05$).

Discussion

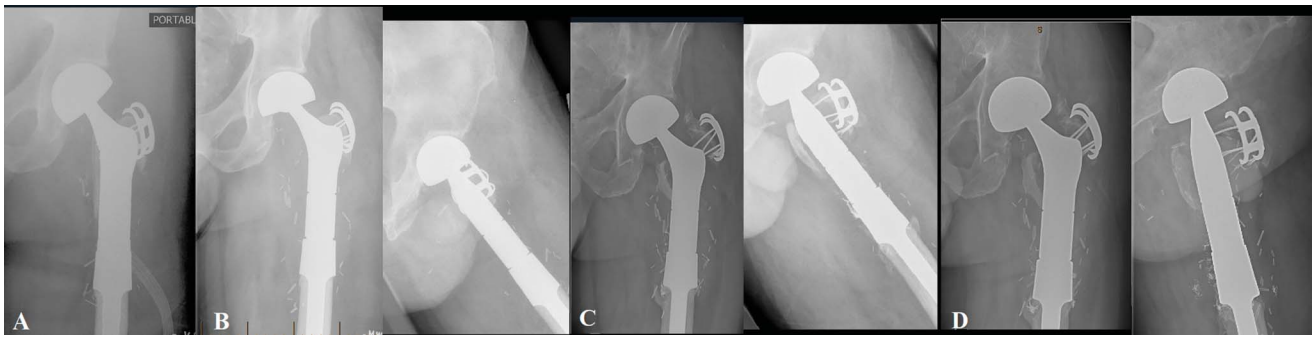
The population of patients diagnosed with proximal femur tumors is diverse and their oncologic survival, variable. Many survivors can expect and aim to have very active lifestyles.[16,17] Therefore, our goals were to maximize functional outcomes and minimize the incidence of complications.[16,17] Restoring function with proximal femoral endoprosthesis remains challenging because no abductor repair technique was ever proven optimal from the literature. Available data are of a low level of evidence.[10,14] Similar to our findings, others have not found improvement in Trendelenburg gait or in the use of walking aids. Similarly, functional tools, such as MSTS or TESS, are not different in patients with GT preservation compared with those with direct soft-tissue repair, and failure was often recorded.[10,14]

Group Comparison

This study is among the largest that analyzed abductor apparatus repair after proximal femur reconstruction with endoprosthesis for tumor. Preservation of the GT, whether repaired with cables or heavy sutures, was not associated with improved rates of Trendelenburg gait nor with independent ambulation and better lower extremity function scores when compared with direct or indirect soft-tissue reattachment. Moreover, the rate of revision surgery was comparable between both reattachment techniques. No notable issues were encountered using grip and cables that led to implant prominence and recurrent symptoms as one may have feared. Moreover, the infection rate was comparable in both groups and similar other reports.[3,8]

The overall dislocation rate in our series reached 11.3% (6/53), comparable with the average rate reported in similar series in the literature, ranging from 7% to 27%.[18-20] The major effect of GT preservation and reattachment in our series was a notable improvement of joint stability, with no episodes of dislocation encountered in group 1, compared with six patients having one or recurrent dislocations in group 2. None of the dislocations required surgical revision, except for one who had a concomitant infection. Abductor deficiency is, among others, a major etiology of an unstable prosthetic hip.[12,21] In our series, we suspect the abductor deficiency to be the major factor accounting for most of the observed instability in the group with direct/indirect soft-tissue repair because both groups had bipolar hemiarthroplasties, were operated on by the same group of surgeons, and had no evidence of implant malposition. Moreover, both groups were comparable for all the remaining possible confounding factors (diagnosis, BMI, and type of surgery). This divergent outcome is most likely related to increased joint restraint achieved earlier with bony GT reinsertion that reduces excessive mobility and allows for improved immediate stabilization and scarring, precluding notable GT migration later on, even after

Figure 1



Left hip radiographs of a patient who had a proximal femur arthroplasty with GT preservation and reinsertion using the grip-and-cables system. (**A**) Immediate anteroposterior postoperative radiograph. **B**, Anteroposterior and lateral radiographs at 3 months of follow-up. **C**, Anteroposterior and lateral radiographs at 1 year of follow-up. **D**, Anteroposterior and lateral radiographs at 10 years of follow-up.

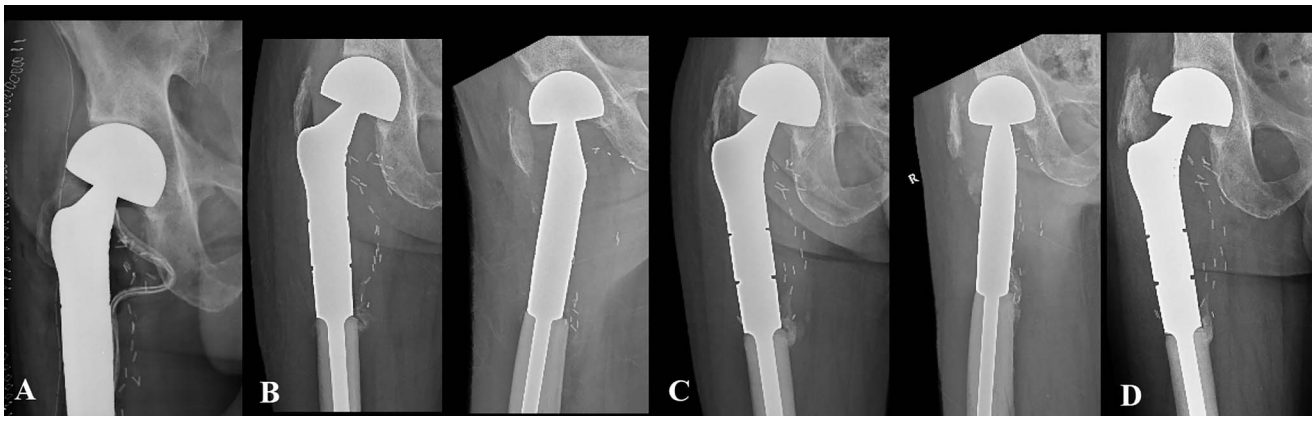
cable rupture. We suspect that with either direct or indirect soft-tissue reinsertion, heavy sutures are less resistant for rigid fixation and may lead to abductor tendon/muscle retraction or proximal migration resulting in scarring and healing in a shortened fashion, causing less containment of the prosthetic hip joint.

Subgroup Analysis

In the 22 patients with preserved GT, 15 had their repair done with the grip-and-cables system. This system evolved through the past decade and was shown to allow effective GT reinsertion with high rates of bone healing and good functional outcomes after revision total arthroplasty.[22] The grip-and-cables system was never evaluated before in massive endoprosthesis where the GT is directly reattached to the porous-coated surface of the prosthesis. In our series, all five patients with rupture of their cables had the rupture within 13 months postoperatively. The mean follow-up of patients with cable repair was 27.4 months (12 to 156). In comparison with other series, the cable rupture rate of the grip-and-cables system after revision hip arthroplasty ranged from zero to 30%.[22-25] This is similar to our findings despite lacking bone-to bone-healing, suggesting fibrous union of the GT to the surrounding soft tissue and to the porous surface of the implant. Some authors reported on GT detachment and migration after fixation with bolt or claw occurring in 45% of the patients within the first 3 months after surgery.[14] Our figures appeared better and could relate to the different implant system used.

This study was not powered to compare surgical and functional outcomes between patients who had GT reattachment using the grip cables system and those who had their GT reattached using heavy sutures. However,

Figure 2



Right hip radiographs of a patient who had a proximal femur arthroplasty with GT preservation and reinsertion using heavy sutures (Ethibond No. 5 sutures). (**A**) Immediate anteroposterior postoperative radiograph. **B**, Anteroposterior and lateral radiographs at 3 months of follow-up. **C**, Anteroposterior and lateral radiographs at 9 months of follow-up. **D**, Anteroposterior radiographs at 18 months of follow-up.

trochanteric displacement was measured for all patients on their follow-up, and it shows markedly less ascension of the GT in patients with a cable grip trochanter repair, at 3, 6, and 12 months of follow-up. Although there are not enough included patients to draw solid conclusions (15 versus 7), these results show that heavy sutures seem to resist less the abduction forces passing through the repair site, when compared with metallic grip-and-cables system. Patients, who had a cable grip GT repair had an initial in situ scarring of their abductor mechanism that resisted additional ascension despite cable rupture in the follow-up (Figure 1). This was not the case with patients who had a heavy suture repair of their GT (Figure 2).

This study has several limitations. The major one is the heterogeneity of the cases between groups 1 and 2 regarding the type of tumor (primary versus metastasis), its size, and its location. This heterogeneity makes multiple noncontrollable factors influence the extent of tumor resection, surrounding soft-tissue defect, and the capacity to preserve the GT. All of these factors might affect hip stability and surgical and functional outcomes; however, despite these, many surgeons in their practice elect to excise the GT even if it could have been preserved with minimal sacrifices. We think that extra efforts should be directed toward GT preservation whenever preservation and reattachment are an option because our finding suggests that it increases markedly the postoperative hip stability. Moreover, despite prospective data collection, our study remains retrospective with risks of selection bias and incomplete data collection. Dedicated functional scores (MSTS and TESS scores) were not always available for the metastatic population as not routinely collected for our nonsarcoma patient. We elected to use alternatively the Trendelenburg gait assessment and the need for assistive ambulating device, similar to other authors, because these criteria reflect indirectly the abductor mechanism function and the subsequent functional limitation related to its impairment.[14] Moreover, it has been shown that MSTS and TESS scores averaged 74.5% and 89.0%, respectively, in patients who lost notable amounts of their abduction strength peak (33% to 66%) after GT reinsertion.[26] Thus, these scores may not appropriately reflect the abductor apparatus performance. One last limitation is the small number of patients in each subgroup of GT repair that limited statistical comparison between the two bony reconstruction methods because of the low incidence of proximal femur sarcomas and the need for a proximal femur arthroplasty in metastatic bone disease.

References

1. Chandrasekar CR, Grimer RJ, Carter SR, Tillman RM, Abudu A, Buckley L: Modular endoprosthetic replacement for tumours of the proximal femur. *J Bone Joint Surg Br* 2009;91:108-112.

2. Chandrasekar CR, Grimer RJ, Carter SR, Tillman RM, Abudu AT, Jeys LM: Outcome of pathologic fractures of the proximal femur in nonosteogenic primary bone sarcoma. *Eur J Surg Oncol* 2011;37:532-536.

3. Calabró T, Van Rooyen R, Piraino I, et al: Reconstruction of the proximal femur with a modular resection prosthesis. *Eur J Orthop Surg Traumatol* 2016;26:415-421.

4. Steensma M, Boland PJ, Morris CD, Athanasian E, Healey JH: Endoprosthetic treatment is more durable for pathologic proximal femur fractures. *Clin Orthop Relat Res* 2012;470:920-926.

5. Harvey N, Ahlmann ER, Allison DC, Wang L, Menendez LR: Endoprostheses last longer than intramedullary devices in proximal femur metastases. *Clin Orthop Relat Res* 2012;470:684-691.

6. Bernthal NM, Schwartz AJ, Oakes DA, Kabo JM, Eckardt JJ: How long do endoprosthetic reconstructions for proximal femoral tumors last? *Clin Orthop Relat Res* 2010;468:2867-2874.

7. Nooh A, Alaseem A, Epure LM, Ricard M-A, Goulding K, Turcotte RE: Radiographic, functional, and oncologic outcomes of cemented modular proximal femur replacement using the "French paradox" technique. *J Arthroplasty* 2020;35:2567-2572.

8. Streitbuerger A, Henrichs MP, Hauschild G, Nottrott M, Guder W, Hardes J: Silver-coated megaprostheses in the proximal femur in patients with sarcoma. *Eur J Orthop Surg Traumatol* 2019;29:79-85.

9. Zucchini R, Sambri A, Fiore M, Giannini C, Donati DM, De Paolis M: Megaprosthesis reconstruction of the proximal femur following bone tumour resection: When do we need the cup? *Hip pelvis* 2021;33:147-153.

10. Ogilvie CM, Wunder JS, Ferguson PC, Griffin AM, Bell RS: Functional outcome of endoprosthetic proximal femoral replacement. *Clin Orthop Relat Res* 2004:44-48.

11. Ropars M, Lambotte J-C, Maximen J, Crenn V, Tronchot A, Huten D: Techniques and outcomes of hip abductor reconstruction following tumor resection in adults. *Orthop Traumatol Surg Res* 2021;107:102765.

12. Elbuluk AM, Coxe FR, Schimizzi GV, et al: Abductor deficiency-induced recurrent instability after total hip arthroplasty. *JBJS Rev* 2020;8:e0164.

13. Kawai A, Backus SI, Otis JC, Inoue H, Healey JH: Gait characteristics of patients after proximal femoral replacement for malignant bone tumour. *J Bone Joint Surg Br* 2000;82:666-669.

14. Groundland J, Brown J, Jones K, Randall RL: Is osseous reattachment of the greater trochanter necessary compared to soft-tissue-only abductor repair in proximal femoral megaprosthesis reconstruction? *J Surg Oncol* 2021;124:115-123, doi:

15. Anract P, Coste J, Vastel L, Jeanrot C, Mascard E, Tomeno B: Proximal femoral reconstruction with megaprosthesis versus allograft prosthesis composite. A comparative study of functional results, complications and longevity in 41 cases [in French]. *Rev Chir Orthop Reparatrice Appar Mot* 2000;86:278-288.

16. Thambapillary S, Dimitriou R, Makridis KG, Fragkakis EM, Bobak P, Giannoudis PV: Implant longevity, complications and functional outcome following proximal femoral arthroplasty for musculoskeletal tumors: A systematic review. *J Arthroplasty* 2013;28:1381-1385.

17. Capanna R, Scoccianti G, Frenos F, Vilardi A, Beltrami G, Campanacci DA: What was the survival of megaprostheses in lower limb reconstructions after tumor resections? *Clin Orthop Relat Res* 2015;473:820-830.

18. Potter BK, Chow VE, Adams SC, Letson GD, Temple HT: Endoprosthetic proximal femur replacement: Metastatic versus primary tumors. *Surg Oncol* 2009;18:343-349.

19. Toepfer A, Straßer V, Ladurner A, Calek A-K, Potocnik P, von Eisenhart-Rothe R: Different outcomes after proximal femoral replacement in oncologic and failed revision arthroplasty patients–a retrospective cohort study. *BMC Musculoskelet Disord* 2021;22:813.

20. Masterson EL, Ferracini R, Griffin AM, Wunder JS, Bell RS: Capsular replacement with synthetic mesh: Effectiveness in preventing postoperative dislocation after wide resection of proximal femoral tumors and prosthetic reconstruction. *J Arthroplasty* 1998;13:860-866.

21. Wera GD, Ting NT, Moric M, Paprosky WG, Sporer SM, Della Valle CJ: Classification and management of the unstable total hip arthroplasty. *J Arthroplasty* 2012;27:710-715.

22. Patel S, Soler JA, El-Husseiny M, Pegg DJ, Witt JD, Haddad FS: Trochanteric fixation using a third-generation cable device—minimum follow-up of 3 years. *J Arthroplasty* 2012;27:477-481.

23. Stewart AD, Abdelbary H, Beaulé PE: Trochanteric fixation with a third-generation cable-plate system: An independent experience. *J Arthroplasty* 2017;32:2864-2868.e1.

24. McCarthy JC, Bono JV, Turner RH, Kremchek T, Lee J: The outcome of trochanteric reattachment in revision total hip arthroplasty with a cable grip system: Mean 6-year follow-up. *J Arthroplasty* 1999; 14:810-814.

25. Kraus MJ, Nowakowski AM: Cerclage breakage in trochanteric revision–high risk for hip endoprosthesis? *Acta Chir Orthop Traumatol Cech* 2017;84:138-140.

26. Crenn V, Briand S, Rosset P, et al: Clinical and dynamometric results of hip abductor system repair by trochanteric hydroxyapatite plate with modular implant after resection of proximal femoral tumors. *Orthop Traumatol Surg Res* 2019;105:1319-1325.