



Original article

Clinical and dynamometric results of hip abductor system repair by trochanteric hydroxyapatite plate with modular implant after resection of proximal femoral tumors



Vincent Crenn^{a,b,*}, Sylvain Briand^a, Philippe Rosset^{b,c}, Jean-Camille Mattei^d, Alban Fouasson-Chailloux^e, Louis-Romée Le Nail^{b,c}, Denis Waast^a, Mickael Ropars^f, François Guoin^{a,b}

^a Orthopedics and Trauma Department, University Hospital Hôtel-Dieu, CHU de Nantes, 1, place Alexis-Ricordeau, 44093 Nantes Cedex 1, France

^b Inserm UMR 1238, Bone sarcomas and remodeling of calcified tissues, faculté de médecine, 1, rue Gaston-Veil, 44035 Nantes cedex 1, France

^c Orthopedics Department, CHU de Tours University Hospital, avenue de la République, 37170 Chambray-lès-Tours, France

^d Orthopedics Department, hôpital Nord, CHU Marseille University, chemin des Bourrely, 13015 Marseille, France

^e Physical Medicine and Rehabilitation Department, hôpital Saint-Jacques, CHU de Nantes University Hospital, 85, rue Saint-Jacques, 44093 Nantes, France

^f Orthopedics and Trauma Department, hôpital Pontchaillou, CHU de Rennes University Hospital, 2, rue Henri-le-Guilloux, 35000 Rennes, France

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ABSTRACT

Introduction: The capacity of the hydroxyapatite-coated trochanteric screwed plates used with modular hip implants to restore abductor system efficacy after proximal femoral tumor resection has never been assessed. We therefore conducted a retrospective study aiming to: (1) quantitatively evaluate abduction conservation on dynamometry according to use of digastric reinsertion, conserving continuity between the gluteus medius and vastus lateralis muscles, or not, and of standard versus small-offset; (2) assess radiographic trochanteric plate fixation; (3) assess functional scores; and (4) assess complications.

Hypothesis: Trochanteric reinsertion better conserves abduction strength when reinsertion is digastric.

Patients and methods: Thirty-one patients undergoing proximal femoral tumor resection between 2006 and 2016 with reconstruction by Stanmore METS™ modular implant with trochanteric plate were included. Twenty-one had digastric fixation between the gluteus medius and vastus lateralis and 10 had simple trochanteric fixation without digastric continuity. Abduction strength was compared between sides on dynamometer. Sixteen patients had full assessment of muscle strength, by a single observer; there were 8 deaths, 5 patients lost to follow-up, and 2 cases of material removal.

Results: Abduction strength conservation versus the contralateral side was $55.2 \pm 23.3\%$ (range, 5.8–86.1%): $66.6 \pm 13.0\%$ (46.4–86.1) with versus $36.0 \pm 24.7\%$ (5.8–63.2%) without digastric continuity ($p=0.01$); severe limp rate was 4/21 when digastric continuity was preserved (19%) versus 6/10 (60%) ($p=0.04$), and radiologic trochanteric reinsertion stability rate was 19/21 (90%) versus 4/10 (40%) ($p=0.005$). Standard femoral offset conserved greater abduction strength: $64.9 \pm 20.0\%$ versus small-offset $45.4 \pm 23.2\%$ ($p=0.05$). Toronto Extremity Salvage Score (TESS) was $89 \pm 9.4\%$, and Musculoskeletal Tumor Society (MSTS) score $75.4 \pm 5.4\%$. There were 6 complications (19%): 4 infections, 1 dislocation, and 1 plate removal; the single dislocation (3%) was in the digastric conservation group. TESS ($90.7 \pm 7.8\%$ vs 88.3 ± 4) and MSTS score ($75.6 \pm 4.0\%$ vs 75.1 ± 3.7) and complications [4/21 (19%) vs 2/10 (20%)] did not differ according to digastric or non-digastric reinsertion ($p=1$).

Conclusions: Abduction strength with a modular implant using a hydroxyapatite-coated trochanteric plate was better conserved by digastric trochanteric reinsertion, resulting in less limping, although the complications rate and functional scores were unaffected. Longer term assessment is needed to confirm this conservation of abduction strength.

Level of evidence: IV, retrospective study without control group.

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* Corresponding author at: Clinique chirurgicale orthopédique et traumatologique, CHU de Nantes, Hôtel-Dieu, 1, place Alexis-Ricordeau, 44093 Nantes Cedex 1, France.
E-mail address: vincent.crenn@chu-nantes.fr (V. Crenn).

1. Introduction

Proximal femoral reconstruction after tumor resection raises the challenge of restoring a functional abductor system in terms of walking and quality of life [1,2]. Modular megaprotheses are often used; reconstruction is simple and reliable, but some authors, such as Donati et al. [1], consider that gluteus medius reinsertion onto the implant is a major issue and may be the weak point of prosthetic reconstruction compared to the allograft-prosthetic composite technique.

The literature on the subject being sparse [2], we undertook a quantitative assessment of the trochanteric reinsertion system of the METS™ megaprosthesis (Stanmore Implants Worldwide Ltd, Elstree, UK) with fixation by a hydroxyapatite-coated plate. The study comprised a consecutive series of proximal femoral tumor resections with reconstruction by megaprosthesis, fixing the abductor system onto the implant by means of the hydroxyapatite-coated plate with 2 screws (METS-HAP).

We conducted a retrospective study aiming to: (1) quantitatively evaluate abduction conservation on dynamometry according to use of digastric reinsertion, conserving continuity between the gluteus medius and vastus lateralis muscles, and of standard versus small-offset; (2) assess radiographic trochanteric plate fixation; (3) assess functional scores; and (4) assess complications. The study hypothesis was that trochanteric reinsertion better conserves abduction strength when reinsertion is digastric (conserving continuity between the gluteus medius and vastus lateralis muscles).

2. Patients and methods

2.1. Patients

A continuous retrospective two-center study (University Hospitals of Nantes and of Tours, France), with a single examiner, included all patients operated on between 2006 and 2016 for *en-bloc* resection of the proximal femur with implantation of a METS-HAP prosthesis with trochanteric fixation (Fig. 1).

Inclusion criteria comprised: functional abductor system attached to a trochanteric medallion, undergoing curative oncologic proximal femoral resection. Exclusion criteria comprised: <6 months' follow-up, and age <18 years at surgery. A METS-HAP prosthesis was implanted in 82 patients. Thirty-one met the inclusion criteria; 16 were assessed on dynamometry (Fig. 2). Data for the 31 patients are shown in Table 1.

3. Methods

After oncologic resection, the METS-HAP implant was used when the trochanteric medallion was conserved, and was as thick as possible up to a maximum 20 mm. Digastric trochanteric reinsertion, conserving continuity between the gluteus medius and vastus lateralis muscles, was implemented whenever possible, depending on resection margins and biopsy trajectory. Six weeks' hemi-bermuda brace immobilization was applied to all patients.

3.1. Assessment

Isometric hip abduction strength was measured by a single observer, using a dynamometer. The protocol was drawn up by a physical medicine and rehabilitation specialist. Measurement was made with the patient in lateral decubitus against a fixed point, optimizing pelvic stabilization by the other hip [3,4]. The final measurement was the mean of 3 maximum intensity trials at 30 s intervals. The measurements were taken prospectively, for the



Fig. 1. X-ray control 4 years after implantation of METS™ megaprosthesis with hydroxyapatite-coated plate and digastric reinsertion.

study, during follow-up at a minimum 6 months. The dynamometer was a Kern electronic traction model (Kern, Balingen, Germany).

Clinical data comprised resection length, type of trochanteric reinsertion, trochanteric bone thickness, and femoral offset. MSTS [5] (Musculoskeletal Tumor Society) score, TESS (Toronto Extremity Salvage Score) [6], MMT (Manual Muscle Test score, from 0 to 5) [7], limping and use of walking aids [8,9] were assessed, and post-operative complications were collected prospectively for patients seen in consultation for dynamometry; data for patients lost to follow-up or deceased were collected retrospectively from medical records. Radiographic stability of the medallion, plate and screws were assessed on double reading by 2 investigators, with a migration threshold of 5 mm on standard follow-up X-ray.

3.2. Statistics

Bilateral dynamometric values were compared on Wilcoxon signed ranks test. Subgroup analysis according to reinsertion type and femoral offset used the Wilcoxon-Mann-Whitney test. Correlations were assessed following Pearson. Quantitative and qualitative data were compared on Student and Fisher tests. Patients with clinical follow-up had no missing data; for patients lost to follow-up or deceased, the 14% missing data were generated by excluding non-valid components. Independent factors for better recovery of abduction strength were analyzed first on univariate linear regression, then selecting all variables correlating at $p < 0.20$ for multivariate analysis. The significance threshold was set at $p < 0.05$. Analyses used IBM SPSS Statistics software, v19.

4. Results

Mean abduction strength was lower on the operated side, with $55.2 \pm 23.3\%$ conservation (range, 5.8–86.1%). Strength in other sectors of motion was likewise lower, but better conserved: adduction, $76.6 \pm 16.2\%$ (range, 43.8–109%); flexion, $68.2 \pm 16.5\%$ (range,

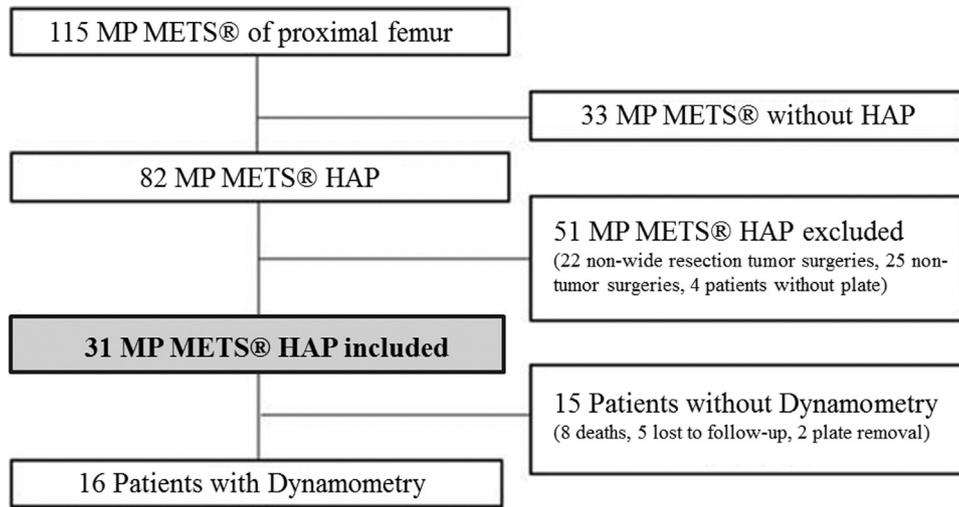


Fig. 2. Inclusion flowchart. MP: megaprosthesis; HAP: hydroxyapatite.

Table 1
Patient data.

	Population (n = 31)
General data	
Age (range) in years	45 ± 21.6 (18–80)
Sex Ratio (M/F)	1.07
Mean follow-up (months)	26.4 ± 22.9 (6–103)
Tumor data	
Osteosarcoma	4 (13%)
Chondrosarcoma	8 (26%)
Ewing's sarcoma	6 (19%)
Soft tissue sarcoma with bone involvement ^a	6 (19%)
Other ^b	7 (22%)
Surgical data	
Resection (mm)	199.1 ± 92.8 (90–400)
Offset: Standard/Small	19 (61%)/12 (39%)
Acetabular implant	
Dual mobility socket	23 (75%)
Hemiarthroplasty	8 (25%)
Conventional socket	
Acetabular reconstruction	
Yes	4 (13%)
No	27 (87%)
Reinsertion	
Trochanteric reinsertion	
Digastric	21 (68%)
Non-digastric	10 (32%)
Trochanteric medallion thickness (mm)	11.1 ± 5.8 (2–22)
Postoperative data	
Hemi-bermuda brace for 45 days	22 (71%)
No brace	9 (29%)

^a 3 myxofibrosarcomas, 2 leiomyosarcomas and 1 undifferentiated sarcoma.

^b 3 single kidney cancer metastases, 2 single thyroid cancer metastases, 1 single undifferentiated sarcoma metastasis, 1 malignant plasmocyte tumor.

39.6–91.7%)(Fig. 3). In digastric reinsertion, abduction conservation was 66.6 ± 13.0% (range, 46.4–86.1%), compared to 36.0 ± 24.7% (range, 5.8–63.2%) in non-digastric reinsertion ($p = 0.01$), confirming the study hypothesis (Table 2) (Fig. 4).

The subgroups did not significantly differ in follow-up time: digastric, 24.4 ± 18.7 months (range, 6–103 months); non-digastric, 30.5 ± 24.8 months (range, 6–70 months). Postoperative follow-up time did not correlate with abduction strength conservation: $\rho, -0.0351$ [95% CI: $-0.5217; 0.4688$] ($p = 0.89$).

Patients with standard 45 mm femoral offset ($n = 8$) showed better abduction conservation than those with small 32.5 mm offset ($n = 8$) ($p = 0.05$) (Table 2) (Fig. 5). The 5 patients with digastric trochanteric reinsertion associated with standard offset showed the best abduction conservation: 76.7 ± 7.8% (range, 68.1–86.1)

($p < 0,001$) compared to all other patients. Offset distribution did not significantly differ according to digastric (small, 41% (9/21); standard, 59% (12/21)) or non-digastric reinsertion [small, 30% (3/10); standard, 70% (7/10)] ($p = 0.29$). Age, gender, resection length and trochanteric medallion thickness did not significantly correlate with abduction conservation. Multivariate analysis identified digastric reinsertion and standard offset as having positive impact on abduction conservation (Table 3).

TESS was 89% and MSTs score 75%. The complications rate was 19%, with 3% dislocation. Severe limp and medallion migration were less frequent with digastric reinsertion, while TESS and MSTs scores and complications showed no significant difference according to type of reinsertion (Table 4).

5. Discussion

Two reconstruction techniques are reported after proximal femoral resection: (1) allograft-prosthetic composites provide satisfactory functional results [10], but encounter problems of availability and of specific complications (resorption, fracture, infection, non-consolidation, etc.) [11]; (2) megaprotheses have the advantages of reliability and ease of implementation [12], but with risk of dislocation and poorer recovery of abduction [13,14]. Dual mobility designs reduce the risk of dislocation [15], but there have been few studies of the abductor system in the anatomic conditions of such massive resection [2], and none have focused on the impact of digastric reinsertion after tumor resection. Progress in bioengineering has led to reinsertion systems, sometimes coated in hydroxyapatite, including the METSTM HAP implant. This system allowed adequate conservation of abduction in 55.2% of the present series. The present results confirmed the hypothesis of greater abduction strength with digastric reinsertion onto the prosthetic trochanter, with 67% conservation versus 36% for non-digastric reinsertion. However, this rate was lower than the 92% reported by Giurea et al. [2] for a trochanteric medallion fixed onto the prosthesis by a polyethylene device, although indications in their study were not exclusively tumoral, and muscle resection was less.

Digastric reinsertion had a positive impact on abduction conservation (Fig. 6). The vastus lateralis seems to act as a stay [16], countering gluteus medius traction and thereby reducing tear-out and stabilizing the medallion. A biological effect is also possible: trochanteric medallion vascularization may be impaired by vastus lateralis sectioning. Najima et al. [17] described retrograde blood flow from the vastus lateralis, conservation of which would

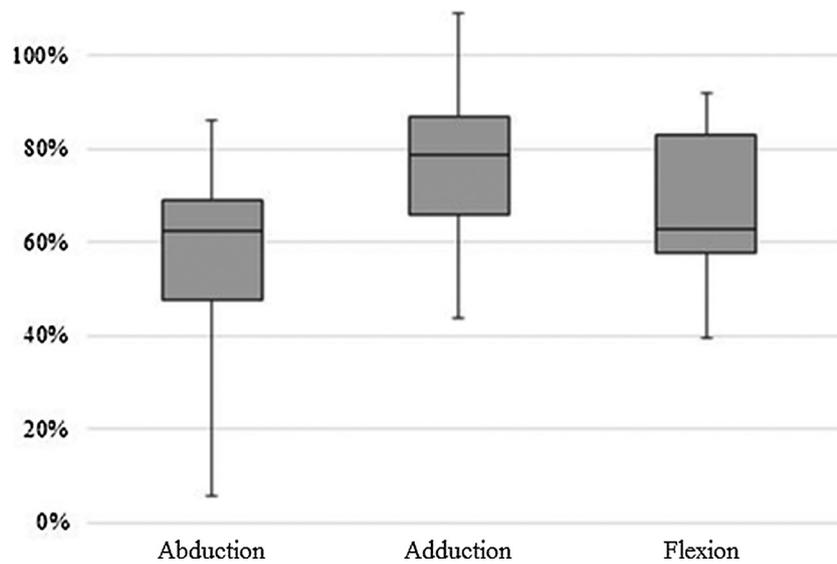


Fig. 3. Box-plots of strength conservation in the various sectors of hip motion.

Table 2

Subgroup analysis of strength conservation in abduction and other sectors of motion according to trochanteric reinsertion and femoral offset.

	Digastric trochanteric reinsertion		<i>p</i>	Type of offset		<i>p</i>
	Yes (<i>n</i> = 10)	No (<i>n</i> = 6)		Standard (<i>n</i> = 8)	Small (<i>n</i> = 8)	
Abduction						
Ratio (%)	66.6 ± 13.0%	36.0 ± 24.7%	0.01	64.9 ± 20.0%	45.4 ± 23.2%	0.05
Operated (<i>n</i>)	140.4 ± 46.8	76.4 ± 57.2	0.04	140.8 ± 52.2	92.4 ± 57.4	0.06
Contralateral (<i>n</i>)	212.6 ± 67.8	241.4 ± 75.4	0.90	219.2 ± 71.0	227.6 ± 132.2	0.58
Adduction						
Ratio (%)	77.9 ± 14.9%	74.5 ± 19.3%	0.31	82.1 ± 9.9%	71.1 ± 19.8%	0.14
Operated (<i>n</i>)	170.2 ± 50.4	169.2 ± 93.2	0.66	185.0 ± 63.2	155.8 ± 70.6	0.38
Contralateral (<i>n</i>)	223.8 ± 62.4	230.4 ± 123.4	0.72	228.6 ± 91.0	224.0 ± 97.2	0.67
Flexion						
Ratio (%)	66.0 ± 14.3%	71.8 ± 20.5%	0.82	71.8 ± 16.9%	64.5 ± 16.3%	0.31
Operated (<i>n</i>)	134.6 ± 53.2	158.8 ± 93.4	0.71	157.4 ± 78.8	130.2 ± 59.2	0.52
Contralateral (<i>n</i>)	209.4 ± 84.0	207.4 ± 79.2	0.86	215.6 ± 90.8	200.4 ± 72.0	0.97

N: newton; 16 patients analyzed (8 deaths, 5 losses to follow-up, 2 material removal).

vitalize the trochanteric medallion [18]. A combination of mechanical and biological factors contribute to medallion osseointegration, accounting for the significant differences between the digastric group and the other patients: better abduction strength conservation (67% versus 36%), greater trochanteric medallion stability (90% versus 40%) and lower rate of severe limping (19% versus 60%). Digastric reinsertion seems to be the best-adapted solution, but tumor location, the requirement for healthy margins and the biopsy trajectory do not always make this possible. It is important that the biopsy trajectory be within a safe zone, to preserve a digastric insertion. When digastric reinsertion can be foreseen to be unfeasible, an alternative may be discussed.

Femoral offset also plays a role in recovery of abduction. Patients with standard offset (45 mm) conserved abduction strength better than those with small-offset (32.5 mm): 65% versus 45%. Mahmood et al. [19] reported that increased femoral offset correlated with greater abduction strength after hip replacement. Preoperative measurement error and fear of muscular overload are the two possible explanations for using smaller offset than the literature would advise. Patients with standard offset and digastric trochanteric reinsertion (*n* = 5) showed the best results, with 76.7%

conservation of abduction strength. The small-offset model of the METS™ HAP megaprosthesis should be used with caution.

The present clinical data were comparable to those of the literature. The MMT score of 3.8/5 was slightly higher than the 3.6 reported by Benedetti et al. [9] and 3 reported by Farid et al. [10]. The MST score of 75.1% was comparable to other reports for megaprostheses: Anract et al. [8], Farid et al. [9] and Benedetti et al. [10] reported respectively 75%, 70% and 68%. The present 19% complications rate predominantly comprised infection (13%), usually in case of associated iliac resection, in line with the literature [20]. There was a single case of dislocation, which is a low rate: Zehr et al. [21] reported 18%, and Puchner et al. [22] 13%. There may be several reasons for this: frequent use of a dual mobility acetabular cup, which has shown efficacy in oncologic surgery with a dislocation rate of only 3.5% [15]; 6 weeks' hemi-bermuda brace immobilization may be another explanation. One plate with screws was removed due to pain following migration of material and the trochanteric medallion; the patient was lost to follow-up, without dynamometry. There were no cases of aseptic loosening.

The main study limitations were the short 26.4 ± 22.9 month follow-up (range, 6–103 months), and small sample size, both

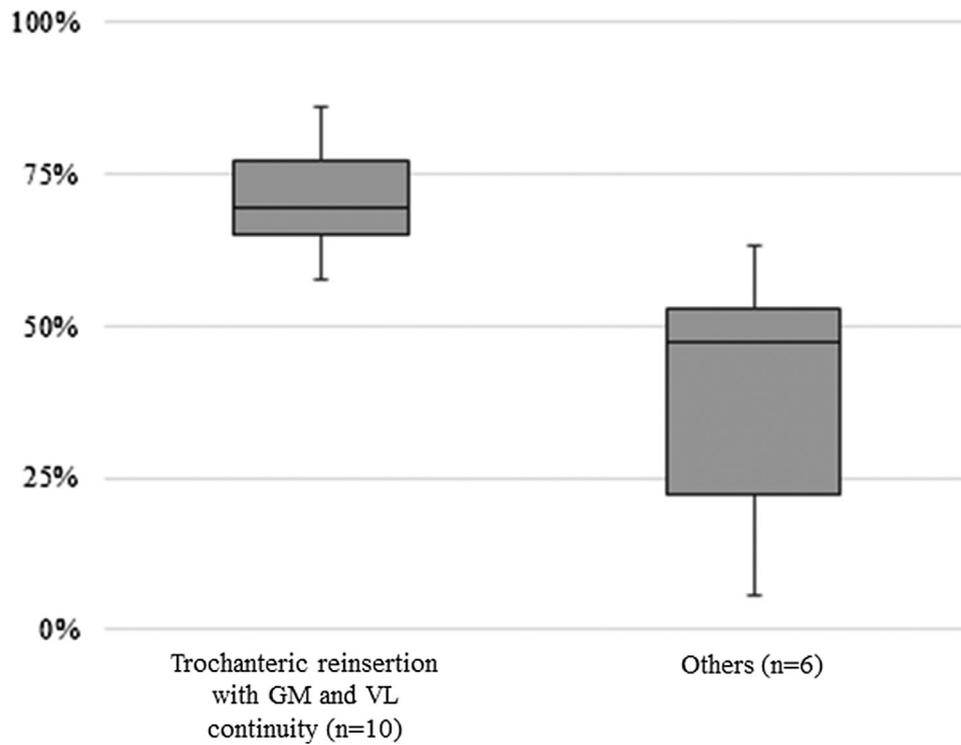


Fig. 4. Box-plots of strength conservation in abduction according to type of trochanteric reinsertion ($p=0.01$).

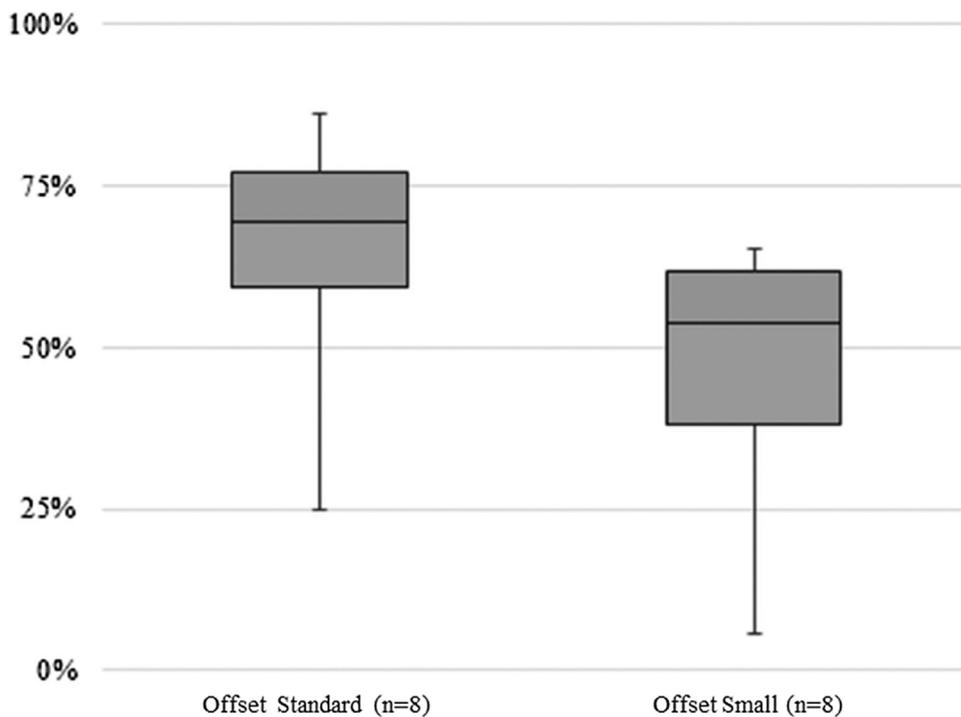


Fig. 5. Box-plots of strength conservation in abduction according to type of femoral offset ($p=0.05$).

due to the relatively recent introduction of the material. Tumor extension biased dynamometry in favor of digastric reinsertion, the other patients probably having greater muscle resection, which was difficult to analyze retrospectively. The dynamometry procedure, however, was rigorous in quantitatively assessing abduction conservation [23,24], and analyses were made by a single observer, limiting measurement bias. Post-surgical follow-up time did not affect abduction conservation.

6. Conclusion

The present study is the first to assess abductor system repair by an HAP-coated plate after proximal femur resection, and to report the importance of digastric trochanteric reinsertion. It completes the work of Chandrasekar et al. [12] on METS™ HAP megaprotheses, with 91% 5-year survival. Dynamometry provided quantitative data on recovery of strength. The specificity and significance of the

Table 3
Univariate linear regression and multivariate model based on abduction strength conservation.

	Univariate analysis		Multivariate analysis	
	Coefficient [95% CI]	<i>p</i>	Coefficient [95% CI]	<i>p</i>
Age (years) ^a	0.17 [−0.45; 0.81]	0.57		
Gender (M)	−14.4 [−39.1; 10.1]	0.22		
Follow-up (months) ^a	−0.03 [−0.51; 0.38]	0.91		
Resection length (mm) ^a	0.07 [−0.05; 0.21]	0.21		
Digastric reinsertion	30.6 [10.6; 50.6]	0.005	30.6 [13.4; 47.7]	0.001
Medallion thickness > 5 mm	26.0 [−3.4; 55.4]	0.08		
Offset (Standard)	19.5 [−3.7; 42.7]	0.09	19.5 [2.9; 36.1]	0.02

^a Quantitative data.

Table 4
Secondary endpoints.

	General population	Digastric reinsertion		<i>p</i>
	(<i>n</i> = 31)	Yes (<i>n</i> = 21)	No (<i>n</i> = 10)	
Clinical data				
Cane	6 (19%)	4 (19%)	2 (20%)	1
Limp	17 (55%)	9 (47%)	8 (80%)	0.07
Moderate	7 (22%)	5 (24%)	2 (20%)	1
Severe	10 (32%)	4 (19%)	6 (60%)	0.04
MMT (/5)	3.8 ± 0.7 (2.3–4.5)	4.0 ± 0.6 (3–4.5)	3.5 ± 0.8 (2.3–4.5)	0.10
Functional scores				
TESS	89.0 ± 9.4% (59–100)	90.7 ± 7.8% (59–100)	88.3 ± 4 (85–96)	1
MSTS	75.4 ± 5.4% (27–100)	75.6 ± 4.0% (27–100)	75.1 ± 3.7 (53–97)	1
Radiography				
Medallion stability	23 (74%)	19 (90%)	4 (40%)	0.005
Plate and screw stability	26 (84%)	19 (90%)	7 (70%)	0.29
Complications				
Global	6 (19%)	4 (19%)	2 (20%)	1
Infection	4 (13%)	2 (9%)	2 (20%)	0.58
Dislocation	1 (3%)	1 (5%)	0 (0%)	1
Plate removal	1 (3%)	1 (5%)	0 (0%)	1
Loosening	0 (0%)	0 (0%)	0 (0%)	1

MMT: manual muscle test [7], TESS: Toronto extremity salvage score [6], MSTS: musculoskeletal tumor society score [5].

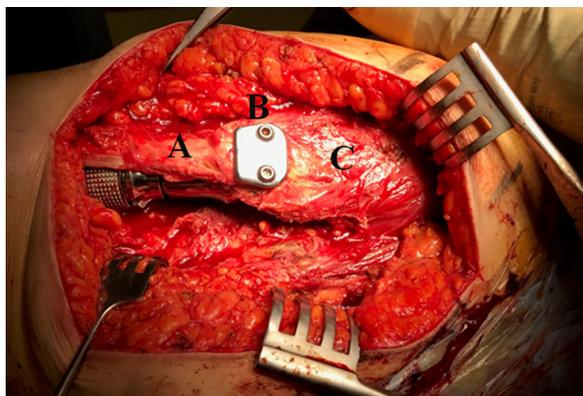


Fig. 6. Digastric reinsertion with tendon continuity on hydroxyapatite plate and modular METS™ prosthesis. A: Vastus Lateralis; B: Trochanter fixed to prosthesis by hydroxyapatite-coated plate; C: Gluteus Medius.

results enable indications for METS™ HAP to be refined, adapting abductor system reconstruction to pre- and intra-operative findings. Digastric trochanteric reinsertion is the best indication for use of an HAP-coated screwed plate, with 67% conservation of abduction strength. Standard offset also improved the quality of the results in abduction. In the short and medium term, combining these two conditions enables the METS™ HAP megaprosthesis to restore abductor function, allowing satisfactory walking and quality of life.

Disclosure of interest

Vincent Crenn, Sylvain Briand, Jean-Camille Mattei, Alban Fouasson-Chailloux, Louis-Romée Le Nail, Denis Waast and Mickaël Ropars declare that they have no competing interest.

François Gouin has no direct commercial relations constituting a conflict of interest with regard to the present article, but is a consultant with Zimmer, Signature Orthopedic France, Amgen SAS, and Groupe Atlanta.

Philippe Rosset has no conflicts of interest to disclose in relation to the present article, but receives fees from SEM, Sanofi, France Implant and Mathys.

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Author contributions

Vincent Crenn and Sylvain: investigators and authors. François Gouin and Mickaël Ropars: study design. Alban Fouasson-Chailloux: dynamometry methodology, and re-editing. Philippe Rosset, Denis Waast, François Gouin and Louis-Romée Le Nail: principal surgeons, and re-editing. Jean-Camille Mattei: re-editing.

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