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Double-plate compound osteosynthesis for pathological fractures of the proximal femur: high survivorship and low complication rate

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Abstract

Introduction Management of pathological fractures of the proximal femur is often challenging. Compound double-plate osteosynthesis has been specifically developed for surgical treatment of these pathological fractures. To our knowledge, this study represents the largest series to date of double-plate compound osteosynthesis with the longest follow-up.

Materials and methods Using our institutional digital database, we identified 61 procedures in 53 patients at the proximal femur. Patients were divided into two groups. A 'primary' group with all cases in which a double-plate compound osteosynthesis was performed as initial procedure ($n = 46$) and a 'revision' group with all cases in which a double-plate compound osteosynthesis was performed as revision procedure after failed previous attempts of internal fixation ($n = 15$). (1) The survivorship of the hip was calculated using the Kaplan–Meier survivorship analysis. (2) Complications were graded using Sink's classification. (3) The functional outcome was quantified with the Merle d'Aubigné and Postel score. (4) Risk factors were identified based on a multivariate Cox-regression analysis.

Results The cumulative Kaplan–Meier survivorship of the primary group was 96% at 6 months, 90% at 1 year, 5 years and thereafter and 83% at 6 months, 74% at 1 year, 53% at 2 years for the 'revision' group ($p = 0.0008$). According to the classification of Sink et al., the rate of grade III and IV complications was significantly lower in the primary group ($p < 0.0001$). The mean Merle d'Aubigné score was 14 ± 7 at 0–3 months, 13 ± 3 at 3–6 months, 15 ± 3 at 6–12 months and 15 ± 4 thereafter ($p = 0.54$). The only multivariate negative predictor was previous surgery with a hazard ratio of 9.2 ($p < 0.006$).

Conclusion Double-plate compound osteosynthesis is a valuable treatment option for pathological fractures in proximal femur with good functional results.

Keywords Pathological fractures · Bone metastasis · Compound osteosynthesis · Proximal femur

Introduction

Modern advancements in oncological therapy have led to a rise in the incidence of pathologic fractures [1, 2]. Management of these often-challenging fractures leads to increased healthcare resource utilization and a substantial socioeconomic burden [3, 4]. While the life expectancy and survival rate at 1 year in patients with metastatic bone disease have been reported to be low [5–8], the overall survivorship of patients after their first pathological fracture has more than tripled in the past 25 years [6, 7, 9].

Due to its exposition to high load transfer [10], the proximal femur is the most common location for pathologic fractures in the appendicular skeleton [11, 12]. Given that implant failure is an inherent risk with any fracture in this region, it is imperative that implants and operative techniques used in management of these pathologic fractures provide long-term stability due to the increased risk of non-union [9, 12]. The aim of treatment is to allow for anatomic stability to rapidly restore patient's mobility and quality of life [9, 12–14].

Numerous treatment options have been described for impending and pathological fractures of the proximal

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femur. These include intramedullary nailing (IMN) [15], endoprosthetic reconstruction [16] or plating with and without augmentation of bone cement [12]. An almost forgotten technique, known as the compound osteosynthesis, has been specifically developed for surgical treatment of these pathological fractures [17, 18]. This technique comprises the reconstruction of the proximal femur using a condylar blade plate together with an intramedullary placed narrow small fragment plate in conjunction with bone cement [18]. This construct has been shown to reach the same weight-bearing stability as an intact femur [17, 18], and is up to three times more stable compared to intramedullary nailing even when augmented with cement [19, 20]. Since muscle insertions are typically preserved with this technique, functional results are superior compared to primary endoprosthetic replacement with regards to range of motion and postoperative limp [21]. In addition, this technique eliminates the risk of post-operative joint instability [2, 22] and has a lower infection rate [23]. Intramedullary nailing is a viable alternative for patients with a life expectancy of less than 6 months [15]. However, IMN offers fewer options for cement augmentation to enhance stability contributing to the elevated risk of implant failure after 6 months [15, 24].

We have been consistently using the original technique of compound osteosynthesis for more than 3 decades. The purpose of this study was to assess the mid- and long-term performance of compound double-plate osteosynthesis for proximal femoral pathological fractures. To our knowledge, this study represents the largest series to date of compound double-plate osteosynthesis with the longest follow-up.

We specifically evaluated (1) the survivorship of the construct, (2) the complications, (3) functional and clinical outcome and (4) predictors for failure.

Table 1 Demography and perioperative data of the study population (61 compound osteosynthesis in 53 patients)

Parameter	Value
Age (years)	63.5 ± 12.2 (39.6 – 92.7)
Number of male hips [percentage]	26 [49%]
Primary diagnosis	
Mamma cancer	14 [26%]
Bronchial cancer	8 [15%]
Multiple myeloma	8 [15%]
Prostate cancer	8 [15%]
Renal cancer	4 [8%]
Other carcinoma	11 [21%]
Adjuvant systemic therapy	
Neoadjuvant chemotherapy	13
Postoperative chemotherapy	6
Neoadjuvant radiotherapy	22
Postoperative radiotherapy	6
Location of osteolysis	
Femoral neck	4 [8%]
Per-/intertrochantric	22 [42%]
Subtrochanteric	23 [43%]
Femoral shaft	4 [8%]
Surgical time (min)	175 ± 64 (75–300)
Blood loss (ml)	1607 ± 1492 ml (250–7000)

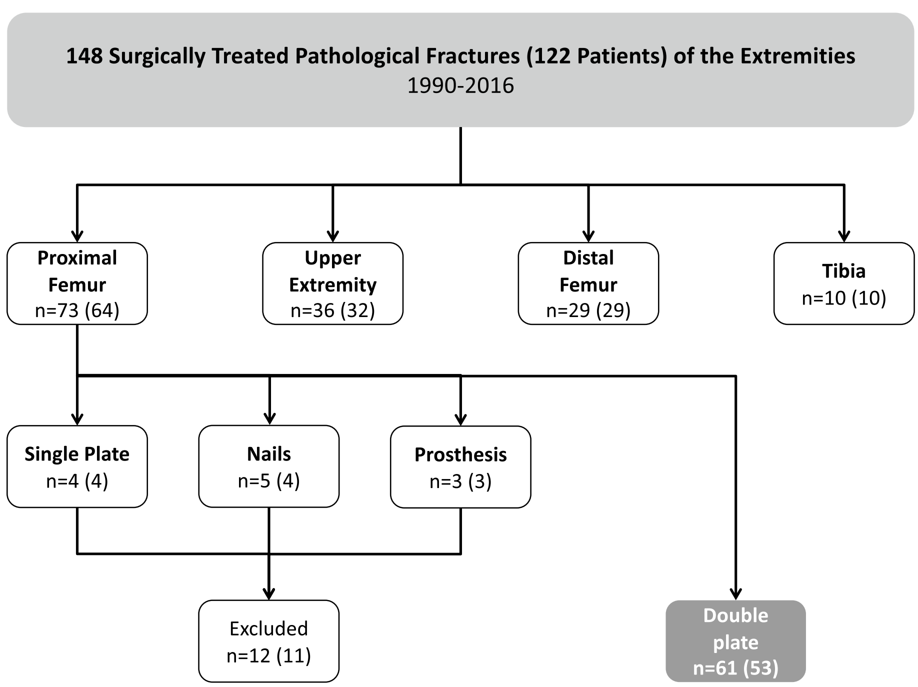

Fig. 1 This figure shows the exclusion and inclusion criteria. Numbers are given as flowchart. [*n* number of surgical procedures (number of patients)]

Materials and methods

This is an IRB approved retrospective review of all patients undergoing management for a pathologic fracture between January 1990 and April 2016.

Using our institutional digital database, we identified 122 patients (148 procedures) undergoing a compound osteosynthesis for any type of pathological fracture of the extremity. The upper extremity was involved in 32 patients (36 procedures), the distal femur in 29 patients (29 procedures), the tibia in 10 patients (10 procedures) and the proximal femur in 64 patients (73 procedures). Of those with proximal femur lesions and fractures, four patients (four procedures) underwent single plating, four patients (five procedures) anterograde femoral nailing, and three patients (three procedures) total or partial hip arthroplasty. This left 61 double-plate compound osteosynthesis in 53 patients for final inclusion in the analysis (Fig. 1). The demographic characteristics of the patients included in the study are shown in Table 1.

The indication for a compound osteosynthesis was consistently a pathological fracture of the proximal femur with an extended osteolysis to the intertrochanteric (27 hips in 23

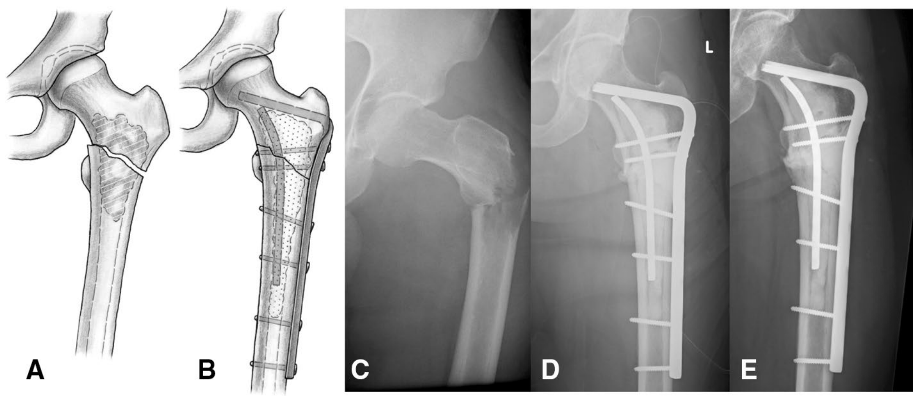

Fig. 2 The technique of augmented compound osteosynthesis of the proximal femur is shown. The metastasis is excised trough an anterior window (**a**). After insertion of a manually contoured 3.5 or 4.5 mm dynamic compression intramedullary plate, a 95° condylar plate is inserted using the standard technique. The fixation screws should cross both plates to reinforce the construction. Finally, the construction is augmented with insertion of bone cement and tightening of the screws (**b**). A pathological subtrochanteric fracture with an extended osetolysis due to a multiple myeloma in a 39-year-old active male patient is shown (**c**). A compound osteosynthesis was performed (**d**) with an excellent result 2 years postoperatively (**e**)

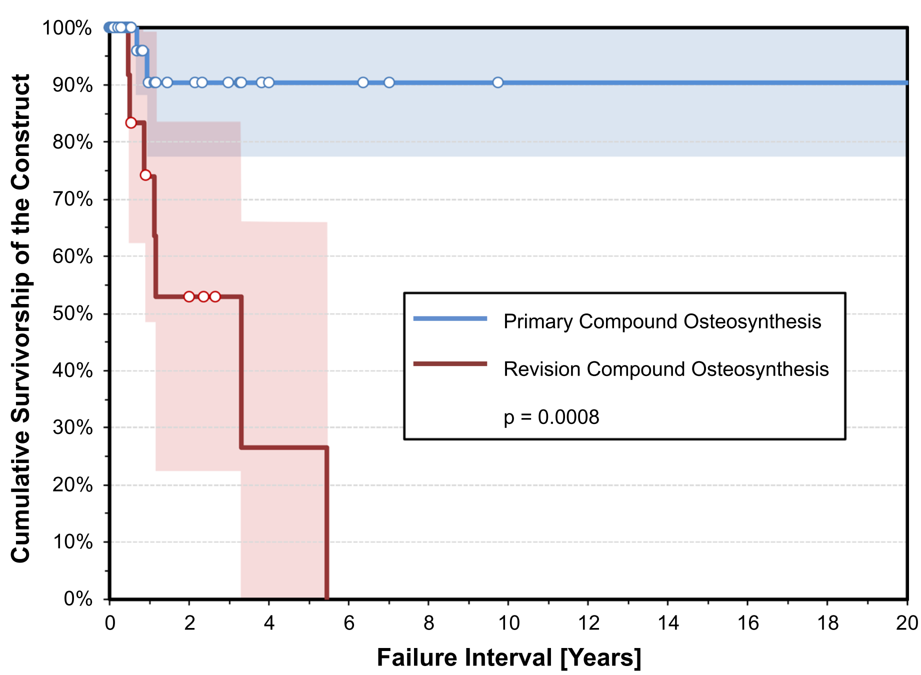

Fig. 3 Survivorship curves of the two study groups including the 95% confidence interval of the compound osteosynthesis with implant breakage or secondary dislocation as endpoints. Circles indicated censored data. The primary compound osteosynthesis group consisted of cases where the procedure was done without previous surgeries. The revision group was defined as having previous attempts of internal fixation

Table 2 Complications of the double-plate compound osteosynthesis for pathological fractures of the proximal femur according to Sink [26] specified for the two study groups

Grade	Original definition according to Sink et al. [26]	Total number of events	Complication rate		List of complications	
			'Primary' group	'Revision' group	'Primary' group ($n=46$)	'Revision' group ($n=15$)
I	A complication that requires no treatment and has no clinical relevance; there is no deviation from routine follow-up during the postoperative period; allowed therapeutic regimens include: antiemetic, antipyretics, analgesics, diuretics, electrolytes, antibiotics, and physiotherapy	–	n.a.	n.a.	Not specifically assessed	Not specifically addressed
II	A deviation from the normal postoperative course (including unplanned clinic visits) that requires outpatient treatment: either pharmacologic or close monitoring as an outpatient	14	8%	40%	Anemia (3), neuropraxia (1), urinary tract infection (2)	Anemia (5), prolonged wound secretion (1), deep vein thrombosis (1), urinary tract infection (1)
III	A complication that is treatable but requires surgical, endoscopic, or radiographic interventions or an unplanned hospital admission	16	9%	80%	Hematoma (1), tumor progression (1), compound osteosynthesis failure (2)	Compound osteosynthesis failure (6), deep infection (1), vascular complication (1), peri-implant failure (4)
IV	A complication that is life threatening, requires ICU admission, or is not treatable with potential for permanent disability	2	2%	1%	Cerebral vascular insult (1)	Tumor progression with secondary hip exarticulation (1)
V	Death[a]	0	0%	0%	None	None

[a] There were five deaths within 4 weeks after surgery, which were all related to the progression of the primary tumor site and not to the surgical intervention itself

patients) and subtrochanteric area (26 hips in 23 patients) with or without extension into the femoral neck (4 hips in 4 patients) and proximal femoral diaphysis (4 hips in 3 patients). At our institution, intramedullary nailing is indicated in pre-terminal patients, primary total hip arthroplasty in those with isolated medial femoral neck fractures, and single plating in patients with osteolysis less than 1 cm.

Our surgical technique has not changed since its description in 1984 [17]. The patient is placed in lateral decubitus position. A straight incision is made starting 5–7 cm proximal to the tip of the greater trochanter extending approximately 20 cm distally. A standard sub-vastus approach is used to expose the fracture. Through an additional anterior window, tumor debulking is performed using an intralesional technique. The calcar area is then prepared using a chisel or a high-speed burr to provide the bed for the intramedullary plate. This plate should be pre-bent and placed as close to the remaining calcar as possible to provide maximal stability. Generally, a 4.5 mm dynamic compression plate (DePuy Synthes, West Chester, PA) is used. The fracture is reduced and temporarily held with clamps and K-wires. A standard 95° condylar blade-plate (DePuy Synthes, West Chester, PA) is inserted using the standard technique [25] with the use of intraoperative fluoroscopy. Unlike a standard internal fixation, as many screws as possible should be placed through both plates to reinforce the construction. Finally, the construction is augmented with methyl-methacrylate cement (Zimmer Biomet, Warsaw, IN) and the screws tightened (Fig. 2).

Postoperatively, the construct stability allows for immediate full postoperative weight bearing as tolerated. Patients were followed on an interdisciplinary basis by oncologists, radio-oncologists and/or by the orthopedic department. The follow-up interval depended on the individual therapy of the primary tumor and included neo-adjuvant or postoperative chemotherapy in 19 patients and radiotherapy in 28 patients. Specifically, we reviewed data regarding patient comorbidities, timing and frequency of reoperations, indications for reoperation, number of revisions, patient survival, and the use of preoperative or postoperative radiation therapy.

We specifically assessed the mechanical integrity of the construct. Mean follow-up was 1.83 years (0.2–25.5). At the moment of the last evaluation for this study, 5 patients were still alive, 1 patient was lost of follow-up and 47 patients were dead.

All postoperative complications were recorded and graded according to Sink et al. [26]. Radiographs were analyzed to assess for implant failure. The functional clinical

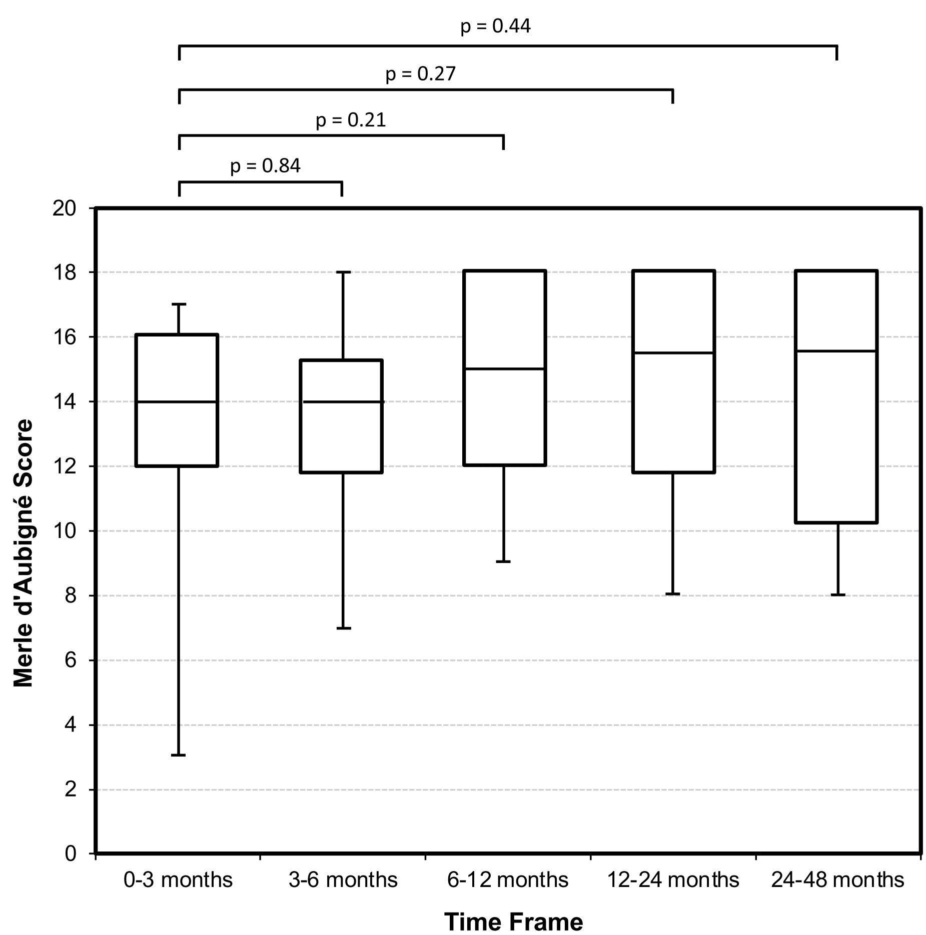

Fig. 4 This figure shows the postoperative course of the Merle d'Aubigné score for different time intervals

Table 3 Cox-regression analysis showing the factors associated with failure defined as revision surgery of the compound osteosynthesis

Factor	Hazard-ratio (95% CI)	*p* value
Sex (male)	0.8 (– 0.5 to 2.1)	0.739
Age	1.0 (+ 0.9 to 1.0)	0.197
Localization		
Pertrochanteric	1.5 (+ 0.1 to 2.8)	0.579
Subtrochanteric	1.2 (– 0.1 to 2.6)	0.745
Femoral neck	0.4 (+ 6.6 to 6.6)	0.343
Femoral shaft	0.1 (– 7.0 to 7.3)	0.568
Previous surgery	9.2 (+ 7.6 to 10.8)	0.006
Primary diagnosis		
Breast cancer	2.5 (+ 1.2 to 3.8)	0.180
Bronchial cancer	0.4 (– 5.3 to 6.0)	0.718
Myeoloma	1.1 (– 0.3 to 2.5)	0.930
Prostate carcinoma	0.1 (– 5.1 to 5.4)	0.421
Renal-cell carcinoma	1.5 (– 0.6 to 3.6)	0.717
Primary diagnosis		
Breast cancer	2.5 (+ 1.2 to 3.8)	0.180
Bronchial cancer	0.4 (– 5.3 to 6.0)	0.718
Myeloma	1.1 (– 0.3 to 2.5)	0.930
Prostate carcinoma	0.1 (– 5.1 to 5.4)	0.421
Renal-cell carcinoma	1.5 (– 0.6 to 3.6)	0.717
Chemotherapy		
Neo-adjuvant chemotherapy	2.0 (+ 0.6 to 3.4)	0.348
Postoperative chemotherapy	0.03 (– 6.3 to 6.4)	0.284
Neo-adjuvant & postoperative	0.8 (– 0.3 to 1.9)	0.659
Chemotherapy		
Neo-adjuvant chemotherapy	2.0 (+ 0.6 to 3.4)	0.348
Postoperative chemotherapy	0.03 (– 6.3 to 6.4)	0.284
Neo-adjuvant & postoperative	0.8 (– 0.3 to 1.9)	0.659
Local radiotherapy		
Preoperative radiotherapy	3.7 (+ 2.0 to 5.3)	0.128
Postoperative radiotherapy	0.4 (– 1.2 to 2.0)	0.250
Pre-& postoperative	0.9 (– 0.3 to 2.0)	0.799
Local radiotherapy		
Preoperative radiotherapy	3.7 (+ 2.0 to 5.3)	0.128
Postoperative radiotherapy	0.4 (– 1.2 to 2.0)	0.250
Pre-& postoperative	0.9 (– 0.3 to 2.0)	0.799

outcome was assessed using the Merle d'Aubigné and Postel score [27]. Since variable follow-up intervals were available, outcomes were grouped from 0–3, 3–6, 6–12 months, and yearly thereafter. The following parameters were assessed for potential confounding negative predictors for failure: age, sex, type of fracture, previous surgery, primary diagnosis, neo-adjuvant/postoperative chemo-/radiotherapy.

Two study groups were formed. The 'primary' group consisted of all cases in which a double-plate compound osteosynthesis was performed as initial procedure ($n = 46$). The 'revision' group consisted of all cases in which a double plate compound osteosynthesis was performed as revision procedure after failed previous attempts of internal fixation such as intramedullary nailing referred from other institutions ($n = 15$ hips).

We used the cumulative survivorship of the construct using the Kaplan–Meier survivorship analysis [28]. The survivorship of the two study groups was compared using the log-rank test. Failure of the implant was defined as a plate breakage or secondary displacement of the fracture. Negative predictors for failure were then identified based on a multivariate Cox-regression analysis [29]. Normal distribution for the Merle d'Aubigné score was assessed using the Kolmogorov–Smirnov test. The Merle d'Aubigné scores among all different time intervals were compared with the Kruskal–Wallis test. The values between the groups were analyzed using the Mann–Whitney U test.

Results

The cumulative Kaplan–Meier survivorship of the primary group with compound osteosynthesis was 96% at 6 months (95% confidence interval [CI] 88–100%), 90% (76–100%) at 1 year, 5 years, 10 years and thereafter, Fig. 3). The cumulative Kaplan–Meier survivorship of the revision group was 83% at 6 months (62–100%), 74% at 1 year (49–99%), 53% at 2 years (23–83%). This difference was statistically significant ($p = 0.0008$).

According to the classification of Sink et al. [26], there were 14 events in 12 patients with a Grade II complication (8 presenting anemia, 3 urinary tract infections, 1 a thromboembolic disease, 1 prolonged wound secretion not requiring revision, and 1 neuropraxia); 16 events in 14 patients with grade III complications (1 hematoma, 1 deep infection, 1 vascular complication, 1 tumor progression, 6 compound osteosynthesis failures and 4 peri-implant failures), 2 events in 2 patients with grade IV (1 metastases progression with secondary hip exarticulation and one cerebral vascular insult). Regarding grade V complications (within 30 days after surgery), there were no deaths directly related to the orthopaedic intervention (Table 2). The rate of grade III and IV complications was significantly lower in the primary group (4/46 cases [9%]) compared to the revision group [13/15 cases [87%], $p < 0.0001$).

The mean Merle d'Aubigné score was 14 ± 7 (range 3–17), at 0–3 months, 13 ± 3 (7–18), at 3–6 months, 15 ± 3 (9–18), at 6–12 months and 15 ± 4 (8–18) thereafter (Fig. 4). There were no differences among all groups ($p = 0.54$) or between the different time intervals (p values in Fig. 4).

The only multivariate negative predictor was previous surgery with a hazard ratio of 9.2 ($p < 0.006$, Table 3). We did not find any association with age, sex, type of primary

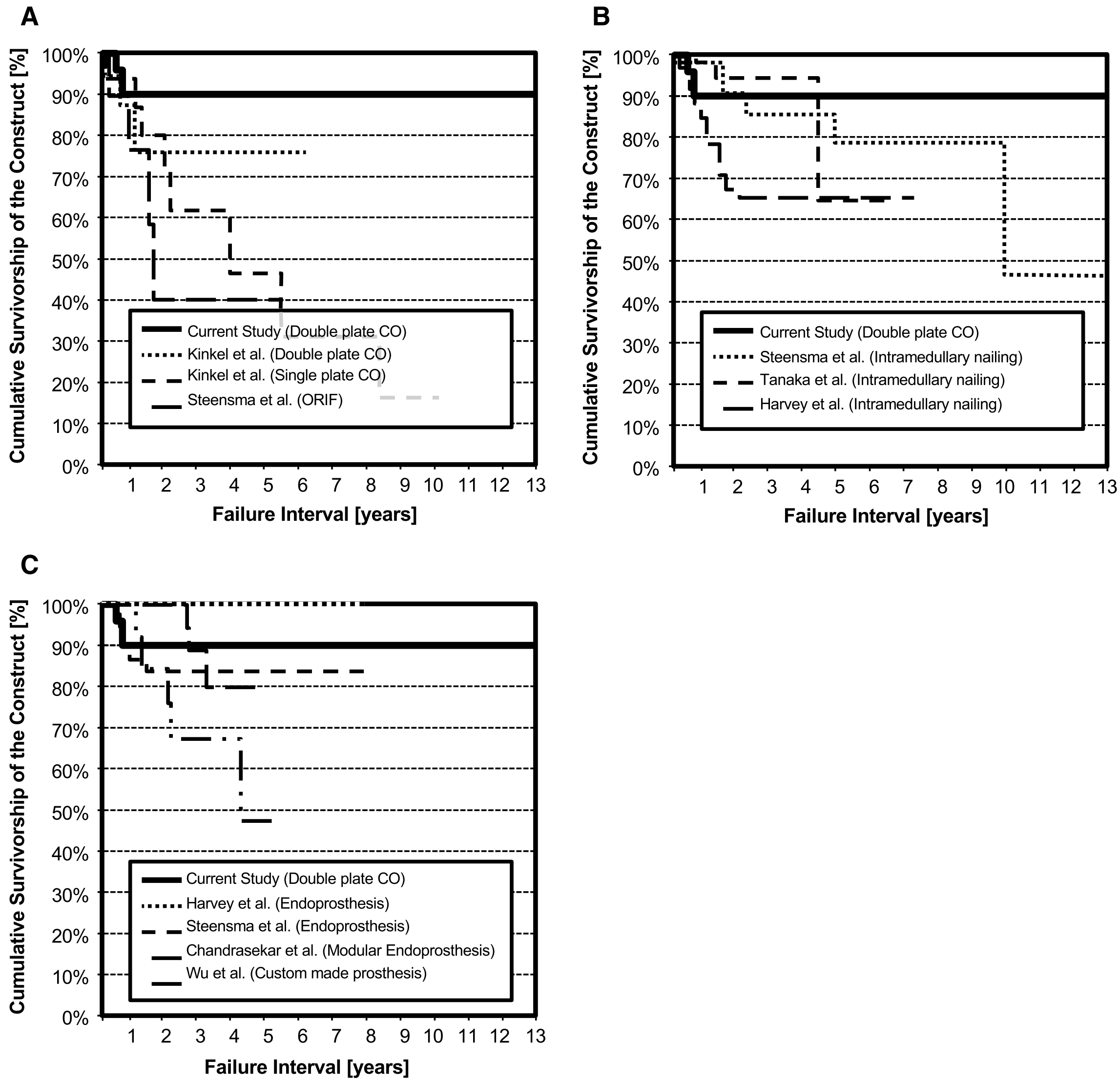

Fig. 5 Comparison of different survivorship curves for available surgical techniques for the treatment of pathological proximal femoral fracture: **a** osteosynthesis and compound osteosynthesis; **b** intramedullary nailing; and **c** endoprosthetic reconstruction

carcinoma, the use of neo-adjuvant chemo- or radiotherapy and type and localization of the fracture.

Discussion

Bony metastases cause considerable morbidity, including pain and impaired mobility. Appropriate management of pathological fractures, especially in the proximal femur is of paramount importance as advances in oncologic management have substantially improved survivorship [7]. Achieving construct stability with a low complication rate is the most challenging factor, as the pathological bone often fails to consolidate leading to incomplete healing and increased rates of nonunion [6, 7, 21]. Thus, as life expectancy increases, cost-effective techniques that provide long-term stability are required [10]. The goals of surgical intervention are to provide pain relief, allow rapid return to full weight bearing, and to decrease hospital stays to improve quality of life in patients with metastatic bone disease [7]. Compound osteosynthesis, even if technically demanding, seems to be a valuable treatment in impending and pathological fractures of the proximal femur [9, 21]. To our knowledge, this study represents largest series to date of double-plate compound osteosynthesis with the longest follow-up.

Survivorship of compound osteosynthesis

We found construct survival rates of 96% at 6 months, and 90% thereafter for primary reconstructions. These results

Table 4 Literature overview of various surgical treatments for pathological fractures of the proximal femur

Author, year	Number	Fixation method	Failure	Follow-up (months)	Complication rate [percent] according to Sink et al. [26]					
					All	I	II	III	IV	V
Peterson et al., 2016 [22]	22	Endoprosthetis (total and hemiarthroplasty)	5%	11 (1–27)			14	5	9	
Rompe et al., 1994 [21]	25	Endoprosthetis (megaprosthesis)	Not reported	18.1	44	n.a.	24	20	0	0
Wedin et al., 2005 [24]	109	Endoprosthesis (45 total/51 hemi/5 bipolar arthroplasty, 8 reconstruction/tumor prosthesis)	10%	19.2	24	n.a.	2	32	1	2
Ya-Nan et al., 2016 [31]	28	Endoprosthesis (16 total hip arthroplasty, 12 hemiarthroplasty)	0%	29 (17.4–40) 23.5 (11.5–40.5)	7	n.a.	7	0	0	0
Lane et al., 1980 [16]	167	Endoprosthesis	0%	10.7	37	34	1	2	0	0
Zacherl et al., 2011 [11]	13	Endoprosthesis (7 hemiarthroplasty, 6 megaprosthesis)	Not reported	8 (0–74)	23	n.a.	0	23	0	0
Harrington et al., 1976 [32]	12	Endoprosthesis	8% (1/12)	15.4	–	–	–	8	–	–
Friedl et al., 1986 [33]	13	Endoprosthesis	Not reported	Not reported	–	–	–	–	–	–
Sarahrudi et al., 2006 [34]	16	Endoprosthesis	Not reported	2.7 (0.2–46)	13	n.a.	6	0	0	6
Sarahrudi et al., 2009 [8]	23	Endoprosthesis (27 total hip arthroplasty, 15 hemiarthroplasty, 4 tumor prosthesis)	8.6%	8 (1.4–16)	26	n.a.	0	22	0	4
Steensma et al., 2012 [35]	197	Endoprosthesis	3.1%	Not reported	3	n.a.	0	3	0	0
Forsberg et al., 2013 [36]	61	Endoprosthesis	7%	7 (3–17)	?	–	–	10	–	–
Harvey et al., 2012 [37]	113	Endoprosthesis	No failure	14 (0.25–86)	18	n.a.	0	18	0	0
Gruber et al., 2009 [38]	59	Endoprosthesis	Not reported	6 (0–102)	12	n.a.	0	10	0	2
Rompe et al., 1993 [21]	25	Compound osteosynthesis (intramedullary K-wires)	Not reported	15.8	16	n.a.	12	4	0	0
Scheuba et al., 1973 [39]	35	Compound osteosynthesis (single plate)	Not reported	Not reported	–	–	–	–	–	–
Muhr et al., 1975 [40]	217	Compound osteosynthesis (single plate)	3%		19	n.a.	6	13	0	0
Walcher et al., 1975 [41]	52	Compound osteosynthesis (single plate)	2%	4–18	6	n.a.	0	4	0	2
Friedl et al., 1986 [19]	30	Compound osteosynthesis (double plate)	Not referred	10.7	–	–	–	–	–	–
Kinkel et al., 2009 [12]	22	Compound osteosynthesis (double plate)	14.3%	14.2 (0–72)	45	n.a.	27	13	0	5
Zacherl et al., 2011 [11]	2	Osteosynthesis (single plate)	50%	8 (0–74)	100	n.a.	n.a.	100	0	0
Gruber et al., 2009 [38]	20	Osteosynthesis (single plate)	Not reported	6 (0–102)	10	n.a.	0	10	0	0
Sarahrudi et al., 2009 [8]	15	Osteosynthesis (dynamic hip screw)	20%	8 (1.4–16)	20	n.a.	0	20	0	0
Sarahrudi et al., 2006 [34]	6	Osteosynthesis (dynamic hip screw)	17%	2.7 (0.2–46)	17	n.a	0	17	0	0
Zacherl et al., 2011 [11]	2	Osteosynthesis (double plate)	50%	8 (0–74)	50	n.a.	n.a.	50	0	0
Tanaka et al., 2016 [15]	80	Intramedullary nailing	4%	11.4 (1–77)	8	n.a.	0	4	0	4
Harvey et al., 2012 [37]	46	Intramedullary nailing	22%	16 (0.25–86)	67	n.a.	–	26	–	–
Zacherl et al., 2011 [11]	38	Intramedullary nailing (5 with cement)	5%	8 (0–74)	8	n.a.	0	8	0	0
Forsberg et al., 2013 [36]	11	Intramedullary nailing	45%	15 (1–56)	–	–	–	–	–	–
Friedl et al., 1986 [19]	10	Intramedullary nailing	Not reported	10.7	–	–	–	–	–	–
Sarahrudi et al., 2006 [34]	51	Intramedullary nailing		2.7 (0.2 –46)	2	n.a.	0	0	0	2
Steensma et al., 2012 [35]	82	Intramedullary nailing	6.1%	Not reported	6	n.a.	0	6	0	0
Gruber et al., 2009 [38]	11	Intramedullary nailing	0%	6 (0–102)	0	0	0	0	0	0
Sarahrudi et al., 2009 [8]	94	Intramedullary nailing	3.2%	8 (1.4–16)	11	n.a.	0	10	0	1

Table 4 (continued)

Author, year	Number	Fixation method	Failure	Follow-up (months)	Complication rate [percent] according to Sink et al. [26]					
					All	I	II	III	IV	V
Friedl et al., 1986 [19]	7	Osteosynthesis (plate)		10.7	–	–	–	–	–	–
Sarahrudi et al., 2009 [8]	2	Osteosynthesis (plate)	50%	8 (1.4–16)	50	n.a.	0	50	0	0
Forsberg et al., 2013 [36]	16	Osteosynthesis (plate)	50%	13 (3–30)	69	n.a.	0	69	0	0
Sarahrudi et al., 2006 [34]	1	Osteosynthesis (plate)	Not reported	2.7 (0.2 –46)	–	–	–	–	–	–
Steensma et al., 2012 [35]	19	Osteosynthesis (plate, dynamic hip screw)	42.1%		42	n.a.	0	42	0	0
Harrington et al., 1976 [32]	118	Multiple techniques (intramedullary nailing or plate/cement)	3%	15.4	27	n.a.	8	13	4	3
Wedin et al., 2005 [24]	37	Multiple techniques (dynamic hip screw or intramedullary nailing with or without cement)	16%	19.2	16	n.a.	0	16	0	0
Bouma et al., 1980 [42]	87	Osteosynthesis w/o cement ($n=49$) Fixation with cement ($n=38$)	10% (5/49)	6 (50%) 12 (30%)	13	n.a.	0	13	0	0

are comparable to the early, previously published reports for this technique [12, 18, 30]. In contrast to the present study, none of these investigations presented a similar follow-up of 2 decades. Comparing our calculated survivorship with the literature, it is evident that double-plate compound osteosynthesis is superior to simple open reduction and internal fixation (Fig. 5a) with or without cement augmentation, intramedullary nailing (Fig. 5b), and comparable if not higher than endoprosthetic replacement (Fig. 5c, Table 4). In revision cases with previous attempts of internal fixation using intramedullary nails, we have observed a lower survivorship of a double-plate compound osteosynthesis construct. In these cases, the mechanical resistance of the proximal femur is weakened by the intramedullary reaming leading to subsequent failure at the shoulder of the blade plate (Fig. 6).

Complications

Comparing our complication rate with the literature is difficult due to a lack of consistency of reporting in literature. However, a comparison of grade III and IV complications according to Sink (Table 4, Fig. 7) is possible since these more severe complications are mentioned in most of the relevant literature. It seems obvious that the rate of complications is highest for open reduction and internal fixation, followed by prosthetic replacement and intramedullary nailing (Fig. 7). The complication rate of primary double-plate compound osteosynthesis in primary cases is low (4%). The majority of postoperative complications were nonspecific regarding to the surgery, as hematoma, anemia or urinary tract infections (Table 2). In revision cases, the complication rate rises to 26% and is mainly related to loss of integrity of the construct as mentioned before. Compared to intramedullary nailing, the double-plate compound osteosynthesis is biomechanically more stable with a very low rate of implant failures or refractures. Compared to prosthetic replacement, the double-plate compound osteosynthesis bears little risk for infection and no risk for dislocation due to the preserved muscle attachments.

Functional outcome

The functional outcome of each patient was evaluated from present data of postoperative controls. We used the Merlé d'Aubigné score [27], as it is a simple score regarding the ability to bear weight, pain and range of motion of the hip, parameters that are usually recorded data in patients history. Even if the majority of patients were dead at the moment of our study, we, therefore, could calculate the score.

Mean score was 13 in the first year after surgery and 15 afterwards. Literature supports better functional outcome for double-plate osteosynthesis compared to tumor prosthesis

Fig. 6 A pathological intertrochanteric fracture of a 79-year-old male patient with prostate cancer is shown (**a**, **b**). Intramedullary nailing was planned at an external institution but had to be abandoned due to the sclerotic bone (**c**). After reconstruction with a double-plate compound osteosynthesis (**d**), the construct failed at the shoulder of the blade plate (**e**). The revision consisted of a tumor endoprosthesis (**f**)

[7, 12]. As we did not compare other surgical techniques, we cannot confirm those results, but the mean functional outcome in our patients was very satisfactory, as most of the patients were pain free and able to bear weight. An important factor for the good functional result of double-plate compound osteosynthesis is the preservation of the insertion of the abductor musculature. With endoprosthetic treatment, the abductor mechanism can be difficult to reattach leading to potential abductor deficiency.

Risk factors for failure of compound osteosynthesis

Interestingly, our analysis of negative predictors leading to implant failure did not reveal any correlation between implant failure or age of patient, sex, primary cancer, localization of the fracture, adjuvant or neo-adjuvant chemotherapy or pre-/postoperative radiotherapy. The only significant multivariate negative predictor for failure of compound osteosynthesis was a history of any previous surgery that has failed (IMN, DHS, ORIF or previous compound osteosynthesis). In our study, of the six patients that suffered failure of their compound osteosynthesis, four had previous surgery with another implant (IMN or single plate osteosynthesis). We recorded a total of seven patients in whom secondary compound osteosynthesis was done after failing of another technique as an intramedullary nailing, dynamic hip screw or single-plate osteosynthesis for a pathological fracture of the proximal femur. Of them, two patients died 4 and 6 months

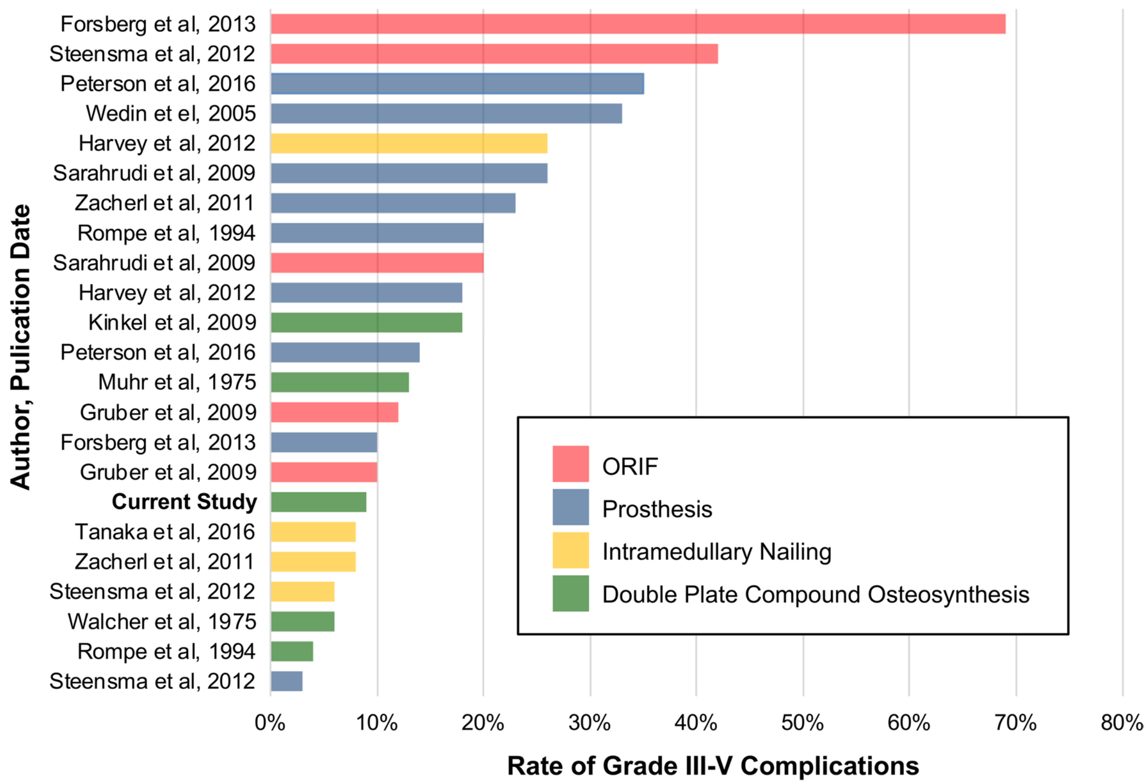

Fig. 7 Comparison of the rate of complications for Grade III and IV according to Sink [26]

after the procedure and showed no failure until then and one patient had no failure until his death 3 years later.

Limitations

Our study has limitations. We do not have a control group so that only literature comparisons to other surgical techniques could be performed. In addition, most of our patients were deceased at the moment the study was made. Therefore, we could only calculate the Merlé d'Aubigné score as a clinical outcome score by reading the medical records to evaluate the functional outcome of this technique. The Merlé d'Aubigné score is easy to reproduce but this score has not been validated with previous studies.

Conclusion

Double-plate osteosynthesis is a cost-effective valuable treatment option for pathological fractures in proximal femur. It provides sufficient stability to allow immediate post-operative weight bearing and range of motion with a good functional result. The complication rate is low compared to all other surgical treatments and the survivorship of the osteosynthesis is higher than with an intramedullary implant. In revision cases with previous attempts of internal fixation, double-plate osteosynthesis has a significantly higher failure rate. In these cases, endoprosthetic reconstruction has become the treatment of choice in our institution.

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Compliance with ethical standards

Conflict of interest All authors declare that they have no conflict of interest.

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