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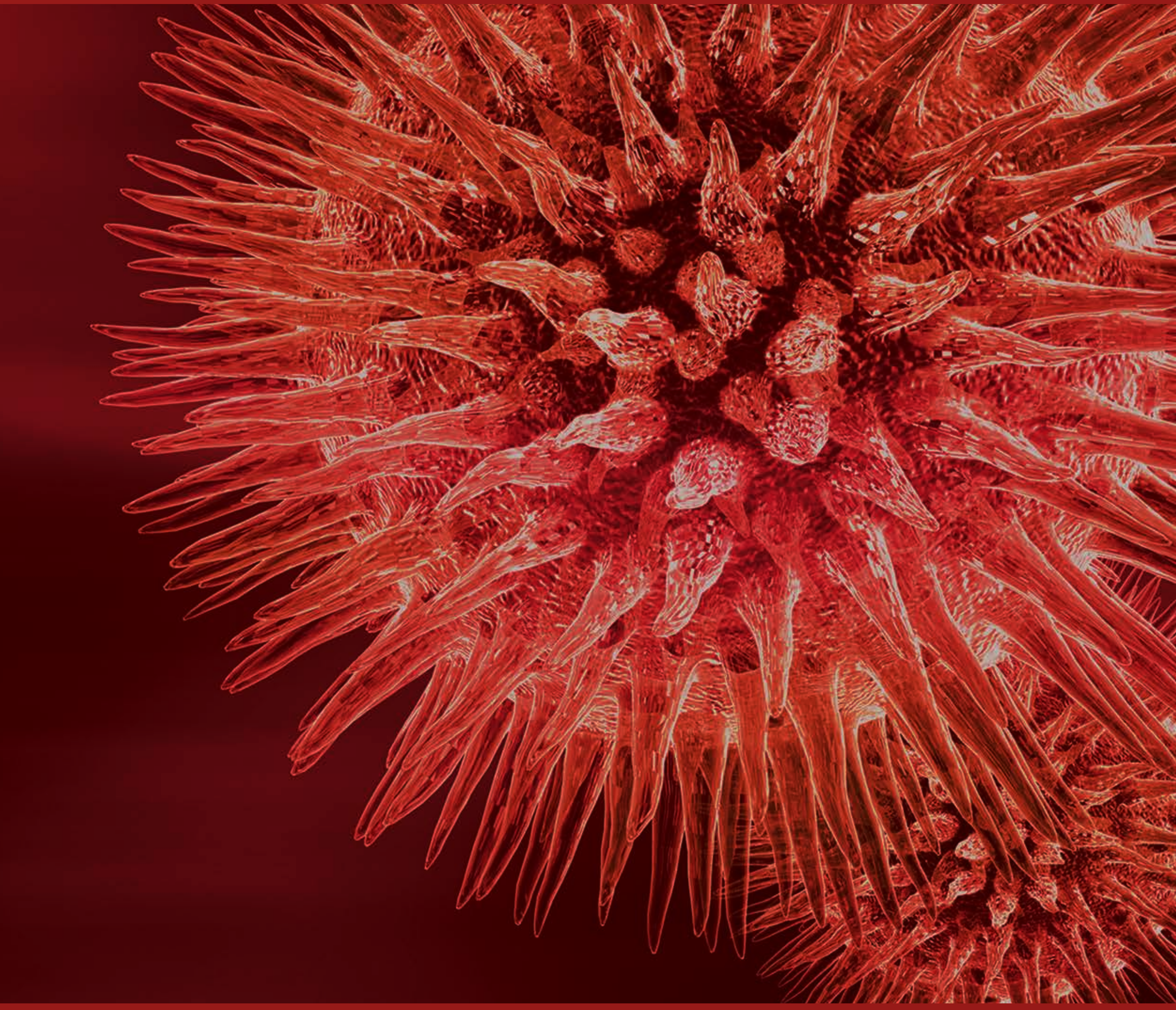
Fragility Fracture Care and Orthogeriatric Comanagement

Guest Editors: Christian Kammerlander, Hitendra K. Doshi, Wolfgang Böcker, and Markus Gosch



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Contents

Hindawi Publishing Corporation
BioMed Research International
Volume 2016, Article ID 2056376, 1 page
http://dx.doi.org/10.1155/2016/2056376

Editorial

Fragility Fracture Care and Orthogeriatric Comanagement

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Received 29 May 2016; Accepted 29 May 2016

Fragility fractures are a major problem resulting in high morbidity and mortality in the older population. Over 80% of such injuries are caused by low energy trauma in patients with underlying osteoporosis. The first-year mortality rate of hip fracture ranges from 12% to 36%; only one-third of patients return to their prefracture functional status eventually and one-third require further nursing home care.

Within this special issue we have a variety of articles focussed on fragility fracture care. One article is about a new approach in treating atypical fractures. Other two articles deal with hip fractures, whereas one is showing that the routine use of cemented stems for femoral neck fracture treatment on the elderly does not lead to higher complication rates and the other article describes that the collapse following the use of a DHS for treating such fractures does impact mobility but not survival of these patients. A very interesting operative strategy is shown for proximal tibial fractures allowing the patients immediate full weight bearing after operation. One more article is focussed on the outcome of elderly hip fracture patients following prolonged ICU treatment.

In summary we have an interesting collection of valuable articles in this upcoming field. The editors want to thank the authors for their contributions.

Christian Kammerlander
Hitendra K. Doshi
Wolfgang Böcker
Markus Gosch

Hindawi Publishing Corporation
BioMed Research International
Volume 2016, Article ID 7627216, 7 pages
http://dx.doi.org/10.1155/2016/7627216

Clinical Study

Is It Time to Phase Out the Austin Moore Hemiarthroplasty? A Propensity Score Matched Case Control Comparison versus Cemented Hemiarthroplasty

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Received 12 October 2015; Revised 7 February 2016; Accepted 16 February 2016

Academic Editor: Hitendra K. Doshi

We compared the Austin Moore hemiarthroplasty versus cemented hemiarthroplasties using a propensity score matched cased control study. For a consecutive cohort of 450 patients with displaced intracapsular neck of femur fractures, 128 matched cases in each group were selected based on age, gender, walking status, nursing home residency, delays in surgery, ASA score, and the Charlson comorbidity score. At a mean follow-up of 16.3 months, we evaluated their outcomes. Significantly more patients with AMA experienced thigh pain (RR = 3.5, 95% CI: 1.67–7.33, $p = 0.000$), overall complications (RR = 4.47, 95% CI: 1.77–11.3, $p = 0.000$), and implant loosening (RR = 8.42, 95% CI: 2.63–26.95, $p = 0.000$). There were no definite cement related deaths in this series. There was no significant difference in mortality, walking status, and the number of revisions between the groups. We support the routine use of cemented hemiarthroplasty instead of the Austin Moore for treating elderlies with displaced intracapsular neck of femur fractures.

1. Introduction

Intracapsular neck of femur fracture is common in the elderly and typically managed by hemiarthroplasty when displaced. The Austin Moore hemiarthroplasty (AMA) was introduced in the 1950s [1]. It is a monobloc cementless hemiarthroplasty system with a nonporous coated collared perforated stem inserted by press fit. Although modern modular porous coated cementless systems and cemented systems have continued to evolve, the AMA remains to be in regular use by developed countries [2].

Despite early reports which suggested that uncemented monobloc stems were prone to mechanical loosening and thigh pain [3–5], they remain to be commonly used. Monobloc stems accounted for nearly one-sixth of the 60000 partial hip replacements for fractures in Australia from 2009 to 2014 [2]. In our region, the AMA remained to be the most used prostheses until 2010 for three main reasons. Firstly, small canal diameters in the local population were common [6], precluding routine usage of the other economical cemented monobloc stems such as the Thompson prosthesis. Secondly, there was insufficient evidence to justify routine use of the more costly modern modular implants [7]. Thirdly, surgeons were concerned about cement related embolic complications and mortalities [8, 9] in frail elderlies.

More recently an additional high quality randomized study by Parker et al. [10] favourably compared cemented monobloc stems against the AMA. It was shown that cemented implants resulted in better function, less pain, and less implant related complications with no apparent increase in the risk of cement related complications. The objective of our study was to reconfirm this by a propensity score (PS) matched case control study in the local population after a resultant change in our healthcare policy.

2. Methodology

We retrospectively reviewed a consecutive cohort of patients in a university affiliated tertiary hospital with intracapsular hip fractures admitted from December 2010 to June 2014 treated by primary hemiarthroplasty. All patients with the Enhanced ICD-9-CM diagnosis code of 820 (Fracture of Neck of Femur) and procedure code of 81.52 (partial hip replacement) were queried and retrieved from the hospital operative record database.

Patients with pathological fractures were excluded. 450 patients with hemiarthroplasties were obtained. The cemented group consisted of modular or monobloc or cemented implants, and the AMA group consisted solely of uncemented prosthesis. As mandated by the local hip fracture pathway [11], all procedures were carried out using the posterolateral approach as described by Moore [1]. All patients were allowed immediate weight bearing after surgery and followed a standard in-patient rehabilitation programme. In the first half of our study period, the AMA was routinely used in most patients while cemented modular stems were used routinely in the second half due to a change in healthcare policy.

PS matching [12] was carried out as an effort to negate confounding at patient selection which may have occurred in very active or very frail patients. Except for the date of surgery, possible confounding variables in affecting decision making were matched between the two groups. These factors were age, sex, preinjury walking state, residency in a nursing home, Charlson comorbidity score [13] (CCS), American Society of Anaesthesiology (ASA) score, and days of delay in surgery. SPSS (Version 23, IBM, Armonk, USA), R (Version 3.10, The R Foundation, Vienna, Austria), and the Thoemmes algorithm [14] (version 3.04) were used for propensity matching and statistical analysis. The standard nearest-neighbour, one-to-one technique was used with a caliper value of 0.2 [15]. Between the two groups, all confounding variables were compared before and after PS matching to ensure that a standardized mean difference of 0.25 or less was obtained and also that none of these baseline variables were significantly different statistically (Table 1).

The territory wide electronic healthcare database which covered all public hospitals and 95% of the local population was reviewed for each patient. The outcome measures were compared under three categories. They were mortality, clinical outcome, and complications. Mortality data was recovered from the territory wide death registry for all patients who were analysed. Only patients with clear clinical documentation of their functional status after rehabilitation were analysed for clinical outcomes. The three research assistants responsible for charting of clinical outcomes were blinded from the type of prosthesis. Four authors assessed the radiological outcomes and complications and each result was cross verified between two authors. Only patients with radiological follow-up of more than 90 days or those with an earlier known complication were included for radiological and complication analysis.

The radiological complications were implant loosening, defined as a continuous radiolucent line of more than 2 mm which surrounded the stem, stem subsidence of more than 5 mm, or gross varus or valgus displacement. Other complications included deep or superficial wound infections, dislocations, intraoperative cracks, and postoperative traumatic and atraumatic periprosthetic fractures. All revision surgeries were recorded.

The Pearson Chi square test was used for dichotomous variables with frequent occurrences and the Fisher exact test was used for variables with small occurrences. The two-tailed t-test was used for continuous variables. A p value of less than 0.05 was taken as statistically significant. Comparisons between the two groups before and after PS score matching were listed in the results of the study. The relative risk (RR) with 95% confidence intervals and the number needed to treat (NNT) was calculated for significant outcomes with AMA being the group exposed to risk.

3. Results

From the database query, there were 146 cemented implants including 114 collarless polished tapered modular cemented stems with a bipolar or monopolar head and 32 cemented monobloc collared hemiarthroplasties. There were 304 uncemented AMAs in the other group. After propensity score matching, there were 128 patients with a cemented stem and 128 matched patients with an AMA. The mean interval for latest clinical follow-up was 20.7 months and the mean interval for latest X-ray was 16.5 months.

In the matched cemented and AMA group, respectively, the mean age was 80.7 and 81.0. There were no differences between the two groups in terms of gender, premorbid walking ability, residence in a nursing home, average delay from admission to surgery, CCS, and ASA scores. For above factors the maximum standardized mean difference was 0.093, indicating two very closely matched groups.

The mean duration of surgery was 67.7 minutes for a cemented hemiarthroplasty and 56.1 minutes for an AMA (Pearson Chi Square significance, $p = 0.000$). There was no statistical difference in the percentage of patients receiving general anaesthesia or receiving blood transfusions. There was no statistically significant difference in cumulative mortality at 1, 3, 6, and 12 months, as well as till the latest follow-up. The mean estimated survival was 43.1 months for both AMA and cemented implants (resp., 95% CI: 39.6–46.6 and 39.0–47.3, log rank test $p = 0.621$). Figure 1 shows patient survival until latest follow up.

One out of three patients with cemented arthroplasty who died within one month had a cause of death related to respiratory failure. This patient had chronic obstructive airway disease and died two days after surgery without an autopsy. We observed no deaths within one month after surgery in the matched group of patients who received the AMA.

Including those with an earlier known mortality or known complication, 79.7% (102) patients with cemented hemiarthroplasty and 82% (105) patients were included into analysis of complications. In these patients, 4.2% (5) cemented and 18.9% (23) AMAs, respectively, had a surgical complication (double sided Fisher's exact test, $p = 0.000$).

Table 1: Group characteristics and balance before and after PS matching.

	Balance before and after PS matching											
	Before PS matching						After PS matching					
	Cemented 146 cases		AMA 304 cases		SMD	p value	Cemented 128 cases		AMA 128 cases		SMD	p value
	Means	n or (range, SD)	Means	n or (range, SD)			Means	n or (range, SD)	Means	n or (range, SD)		
Age	79.0	(36.9–98.2, 8.7)	84.4	(53.7–101, 7.1)	0.616	0.000	80.7	(62.6–98.2, 7.2)	81.0	(53.7–95.9, 7.1)	0.031	0.759
Age above 80	47.9%	70	74.7%	227	0.619	0.000	54.7%	70	56.3%	72	0.032	0.802
Males	28.8%	42	29.9%	91	0.026	0.799	27.3%	35	31.3%	40	0.086	0.492
Independent walker	52.1%	76	34.5%	105	0.349	0.000	46.9%	60	44.5%	57	0.047	0.707
Nonfunctional walker	4.8%	7	10.9%	33	0.283	0.034	5.5%	7	5.5%	7	0.000	1.000
Nursing home residence	13.0%	19	23.7%	72	0.316	0.008	14.1%	18	17.2%	22	0.093	0.491
Days delay in operation	2.1	(0–72, 6.0)	1.8	(0–44, 3.0)	0.057	0.426	2.1	(0–72, 6.4)	2.2	(0–44, 4.4)	0.008	0.946
3 days delay in operation or more	11.6%	17	9.5%	29	0.071	0.490	10.2%	13	12.5%	16	0.069	0.554
ASA score	2.5	(1–4, 0.6)	2.7	(1–4, 0.5)	0.331	0.001	2.5	(1–4, 0.6)	2.5	(1–4, 0.6)	0.000	1.000
ASA score 3 or above	46.6%	68	66.1%	201	0.411	0.000	49.2%	63	51.6%	66	0.046	0.708
Charlson Comorbidity Score	2.1	(0–13, 2.8)	2.6	(0–14, 2.6)	0.180	0.063	2.1	(0–13, 2.8)	2.0	(0–9, 2.2)	0.031	0.787
Charlson Comorbidity Score 5 or above	14.4%	21	21.1%	64	0.164	0.091	14.1%	18	13.3%	17	0.023	0.856
Length of clinical follow-up	17.0 m	(0–53.2, 11.8)	22.8 m	(0.1–55.3, 14.9)		0.000	16.7 m	(0–53.2, 11.6)	24.7 m	(0.4–55.3, 15.2)		0.000
at least 3 months	85.6%	125	81.3%	247		0.252	85.2%	109	82.0%	105		0.500
at least 9 months	65.8%	96	72.4%	220		0.151	64.8%	83	75.0%	96		0.076
Length of radiological follow-up	14.3 m	(0–53.2, 11.6)	17.2 m	(0–55.3, 14.0)		0.030	14.0 m	(0–53.2, 11.4)	19.0 m	(0–55.3, 15.0)		0.003
at least 3 months	77.4%	113	70.7%	215		0.136	76.6%	98	70.3%	90		0.258
at least 9 months	50.7%	74	56.3%	171		0.267	50.8%	65	59.4%	76		0.167

Pearson Chi square test for dichotomous variables.
Two-tailed Independent sampled t-test for continuous variables.
(SMD) Standardized Mean Difference = difference in means ÷ Standard deviation.

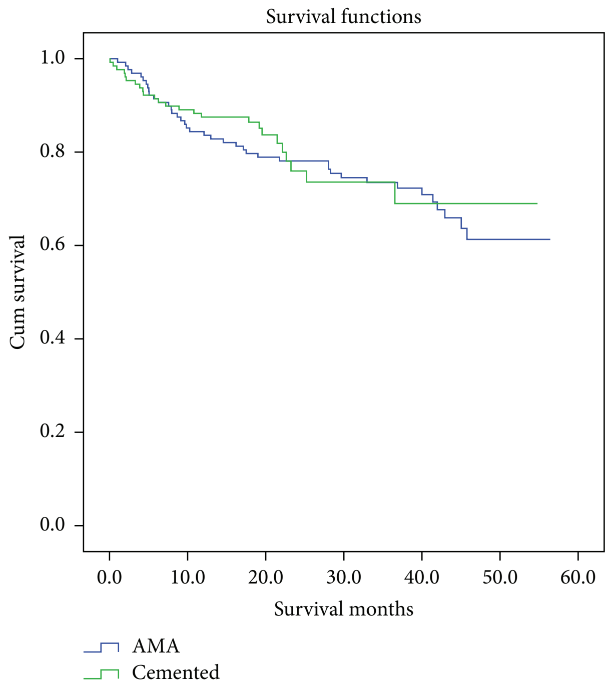

Figure 1: Patient survival until latest follow-up. Log rank test p = 0.621.

2.5% (3) cemented and 19.7% (24) AMAs (double sided Fisher's exact test, $p = 0.000$) had definite radiological evidence of implant loosening or subsidence of more than 5 mm before one year. One and four patients, respectively, had a posterior dislocation of the prosthesis. One and three patients, respectively, had deep infection. The differences in incidence of dislocation and infection were not statistically significant (double sided Fisher's exact test, $p = 0.369$ and $p = 0.621$, resp.).

One cemented hemiarthroplasty and seven AMAs had an intraoperative crack (double sided Fisher's exact test, $p = 0.056$). Additionally, there were five cracks in the cemented group as a result of an intended AMA insertion which led to conversion to a cemented system without further consequence, and these were not counted as a complication in either group. Cerclage wires were placed for all seven cracks which occurred at AMA insertion and five of them still had eventual implant loosening.

3.4% (4) of cemented hemiarthroplasties versus 6.6% (8) of AMAs received one or more reoperations (double sided Fisher's exact test, $p = 0.238$). In the cemented group, this included one open reduction and internal fixation of periprosthetic fracture, one conversion to a long stemmed total hip arthroplasty for aseptic loosening, one debridement procedure of deep infection, and one open reduction of an incarcerated posterior dislocation with sciatic nerve palsy. For the AMA group, there were three stem revisions for aseptic loosening, two reentries for cerclage wiring of missed intraoperative cracks, one multistaged revision for septic loosening, one debridement procedure of deep infection, and one Girdlestone procedure for aseptic loosening with dislocation.

7.1% (8) of cemented hemiarthroplasties patients versus 24.8% (29) of AMAs experienced clinically significant thigh pain or hip pain at any time point during the follow-up period; this difference was statistically significant (double sided Fisher's exact test, $p = 0.000$).

88.3% (113) of cemented hemiarthroplasty and 91.4% (117) of AMAs had adequate clinical data to grade their maximum walking status after rehabilitation. In terms of walking status, there was no statistically significant difference between the two groups.

In summary of the significant findings, compared to patients with a cemented hemiarthroplasty, patients with an AMA were 3.5 times more likely to have thigh pain (RR: 95% CI: 1.67–7.33), NNT = 5.6 (95% CI: 3.7–11.8), 4.47 (RR: 95% CI: 1.77–11.30) times more likely to have complications, NNT = 5.9 (95% CI: 3.8–12.5), including 8.42 (RR: 95% CI: 2.63–26.95) times more likely to have implant loosening up to latest follow-up, NNT = 4.6 (95% CI: 3.2–7.8), and 7.77 times (RR: 95% CI: 2.41–25.01), NNT = 5.0 (95% CI: 3.5–9.0), more likely to have implant loosening within one year after surgery. Moreover, patients with an AMA had an increased but statistically insignificant trend in having more revisions, intraoperative cracks, dislocations, and infections.

In our locality, the cost difference between a cemented hemiarthroplasty and an AMA is around USD$400. Based on the calculated NNT, cemented hemiarthroplasty would potentially be cost saving if the following expenditures are exceeded in managing each bad outcome: thigh pain (NNT = 5.6, USD$2240), any complications (NNT = 5.9, USD$2360), and loosening (NNT = 4.6, USD$1840). However, since cost analysis was not the main objective of the current study, the above calculations can only be taken as approximate estimations.

4. Discussion

In this study we were able to sufficiently prove that routine usage of cemented stems resulted in improved outcome of patients within one year after surgery. Our findings agreed well with the two previous randomized studies [5, 10].

After a number of unmatched studies which suggested inferiority of the AMA against cemented hemiarthroplasties [3, 4, 8, 16], Sonne-Holm et al. [5] were the first to publish a Randomized Clinical Trial (RCT) of 112 patients comparing the uncemented AMA against the cemented AMA in 1982. It was concluded that cementation of the same prostheses resulted in significantly better pain relief and gait function. Despite that, the practice of cementing an AMA was not widely accepted because of its design intent and worries of extreme difficulty in removal due to cement interlocking with a perforated stem. Twenty years later, Parker et al. performed another high quality RCT with 400 patients comparing the cemented Thompson against the uncemented AMA. The cemented group had less pain and better mobility [10]. These studies have heavily influenced a number of following meta-analyses [17–19], where authors also conclude that cementation improved pain and function. Our study is the third such comparative study that used matched data of AMAs versus cemented hemiarthroplasties.

One patient who received a cemented prosthesis in our study died from cardiopulmonary related complications two days after surgery. However, since an autopsy was not carried out, it was uncertain whether this may have been related to cement thromboembolic events. The risk of cementation remains to be important in patients prone to cardiopulmonary and cerebrovascular compromise [9]. Our study and the other RCTs are likely underpowered to reiterate the small but significant (0.3% versus 0.04%, Pearson Chi square, $p = 0.02$) risk of intraoperative deaths observed from 8639 cemented and 2477 uncemented hemiarthroplasties in the Norwegian hip registry [8].

As shown by other studies, the cemented prosthesis usually resulted in better walking function in addition to thigh pain. This finding however was only reflected in our results (Table 2) before PS matching and mitigated after matching. We therefore believe that walking outcome is more affected by the patient's premorbid status. Patients with poor cognitive status and limited rehabilitation potential may have similar walking function regardless of the implant being used.

More patients had intraoperative cracks during implantation of AMAs. Despite only having borderline statistical significance in this study, it is noteworthy that five additional cracks that were not counted as complications in the cemented group actually resulted from intended AMA implantations. This is in agreement with other studies [8, 17, 20], showing that cementless hemiarthroplasties are associated with more iatrogenic fractures in osteoporotic patients.

It is uncertain here whether better leg length, offset, and soft tissue tension restoration provided by modular cemented implants may have resulted in a small but insignificant trend of less dislocations in cemented implants. It is also unknown from our results whether routine use of gentamicin loaded antibiotic cement may have led to a small but insignificant trend of less infections in cemented hips.

It should be noted that older cementless monobloc stems such as the AMA are distinct from modern cementless modular porous coated prosthesis. The monobloc stems have a number of notable shortcomings. Firstly, the AMA's nonmodular design does not allow for adjustment of the femoral neck length and total hip conversions must be performed with a stem exchange. Secondly, the AMA has a matt and nonporous coated surface finish, providing less surface friction and less early stability and no opportunity for bone ingrowth when compared to porous coated stems. Thirdly, the AMA has a concave medial and convex lateral stem profile and comes in only two available sizes, providing less reliable fitting and three-point stability when compared to double or triple tapered modern stems that are made to fit a variety of canals. These fundamental design differences should be considered when interpreting the conclusions from a number of recent meta-analyses [17–19] which generally compared cemented and cemented hemiarthroplasties and were heavily influenced by the inferior outcomes of the older cementless monobloc stems.

In a number of more recent studies, modern porous coated cementless hemiarthroplasties had mixed outcomes when compared against cemented implants. Rogmark et al. [21] observed inferior cementless implant survival at five years and more periprosthetic fractures in patients older than 75 years but not younger patients in the Norway and Swedish national registry. Langslet et al. [22] demonstrated in an RCT that while modern porous coated cementless hemiarthroplasties had a higher risk of periprosthetic fractures, patients had better hip scores after 5 years. Two other RCTs by Talsnes et al. [23] and Deangelis et al. [24] demonstrated similar functional outcome and low complication rates for modern modular cemented and cementless designs in the first year. In all, not all of the newer studies agreed with each other and the older studies with cementless monobloc stems. Better powered studies and renewed meta-analysis are needed. It is also possible that subgroups of patients may benefit differently from specific modern cemented or uncemented prosthesis.

There are a number of limitations in this study. Firstly, this is a retrospective nonrandomized study. We attempted to negate confounding by PS matching. As there were many cognitively impaired patients who were unable to give consent for an RCT, this may be the next best way to do a comparison study. PS matching has been used in a large number of clinical studies and is becoming increasingly popular [12, 25]. The caliper nearest-neighbour matching technique is one of the standard methods in obtaining optimal balance in moderate to large samples [15]. The main drawbacks of propensity score matching are the trade-off in statistical power and systemic failure when some important confounding factors are overlooked. In our study we eliminated 194 cases. The findings may not apply to the frailest and most active patients as they may have been excluded during matching. This also reduced this study's statistical power in detecting less remarkable differences.

Secondly, the group of cemented hemiarthroplasties was not homogenous. It comprised patients with cemented Thompsons, cemented AMAs, and cemented collarless polished tapered modular stems with monopolar or bipolar heads. Nonetheless, we viewed them as a single group based on the current literature which suggested minimal to no difference between these cemented implants [26, 27]. Lastly, the clinical outcome analysis in this study was partially flawed because standardized scoring systems were not used and 19% of patients either died or had insufficient clinical documentation at follow-up.

5. Conclusion

Cemented hemiarthroplasties outperformed the AMAs in terms of pain control, implant stability, and complication rate. We detected no increased early mortality related to cementing complications. We support the routine use of cemented hemiarthroplasties for geriatric intracapsular hip fractures.

Disclosure

This study was not supported by any external research funding.

Table 2: Outcomes compared between cemented versus AMA groups before and after PS matching.

	Outcomes before and after PS matching											
	Before PS matching					After PS matching						
	Cemented 146 cases		AMA 304 cases		p value	Cemented 128 cases		AMA 128 cases		p value	Relative risk (95% CI)	NNT (95% CI)
	Mean	n or (range, SD)	Mean	n or (range, SD)		Mean	n or (range, SD)	Mean	n or (range, SD)			
Duration of Surgery	69.1 mins	(21–171, 23.6)	53.7 mins	(20–135, 21.4)	0.000	67.7 mins	(21–139, 22.5)	56.1 mins	(21–135, 21.6)	0.000		
General anaesthesia	26.7%	36	17.4%	53	0.022	25.8%	33	18.0%	23	0.131		
Received blood transfusion	35.6%	52	38.2%	116	0.602	35.9%	46	32.0%	41	0.510		
Died at 1 month	2.1%	3	3%	9	0.577	2.3%	3	0.0%	0	0.082		
Died at 3 months	4.8%	7	7.9%	24	0.225	4.7%	6	3.1%	4	0.521		
Died at 6 months	8.2%	12	11.8%	36	0.244	8.6%	11	8.6%	11	1.000		
Died at 12 months	12.3%	18	19.1%	58	0.074	12.5%	16	15.6%	20	0.474		
Total length of stay (mean, SD)	29.3 days	(2–292, 26.9)	29.6 days	(5–130, 16.8)	0.880	29.8 days	(2–292, 28.4)	31.8 days	(12–130, 18.0)	0.508		
Fulfill clinical analysis criteria	88.4%	129	86.5%	263	0.585	88.3%	113	91.4%	117	0.410		
post-op functional walker	83.7%	108	74.9%	197	0.053	81.4%	92	80.3%	94	0.868		
post-op recreational walker	21.7%	28	5.3%	14	0.000	15.9%	18	9.4%	11	0.165		
Unable to maintain walking function	42.6%	55	44.9%	118	0.746	45.1%	51	49.6%	58	0.512		
post-op thigh pain	6.2%	8	22.4%	59	0.000	7.1%	8	24.8%	29	0.000	3.50 (1.67–7.33)	5.6 (3.7–11.8)
Fulfill complication analysis criteria	80.1	117	81.3	247	0.779	79.7%	102	82.0%	105	0.635		
Cracks from attempted AMA	4.3%	5				4.9%	5					
Complications	4.3%	5	21.9%	54	0.000	4.9%	5	21.9%	23	0.000	4.47 (1.77–11.30)	5.9 (3.8–12.5)
Loosening	2.6%	3	23.1%	57	0.000	2.9%	3	24.8%	26	0.000	8.42 (2.63–26.95)	4.6 (3.2–7.8)
Loosening before 1 year	2.6%	3	21.9%	54	0.000	2.9%	3	22.9%	24	0.000	7.77 (2.41–25.01)	5.0 (3.5–9.0)
Revision surgeries	3.4%	4	6.9%	17	0.233	3.9%	4	7.6%	8	0.374		
Intraoperative crack	0.9%	1	5.3%	13	0.043	1.0%	1	6.7%	7	0.065		
Dislocations	0.9%	1	3.2%	8	0.282	1.0%	1	3.8%	4	0.369		
Infections	0.9%	1	2.8%	7	0.445	1.0%	1	2.9%	3	0.621		
Traumatic periprosthetic fractures	0.9%	1	1.2%	3	1.000	1.0%	1	0.0%	0	0.493		

NNT: number needed to treat.
Double sided Fisher's exact test for dichotomous variables.
Two-tailed Independent sampled t-test for continuous variables.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

Acknowledgments

The authors would like to acknowledge Ms. Kathine Ching, Ms. Margaret Ho, Ms. Amanda Li, Ms. Elaine Tian for data recovery and entry.

References

[1] A. T. Moore, "The self-locking metal hip prosthesis," *The Journal of Bone & Joint Surgery—American Volume*, vol. 39, no. 4, pp. 811–827, 1957.

[2] S. Graves, D. Davidson, R. DeSteiger et al., *Australian Orthopaedic Association National Joint Replacement Registry Annual Report*, Australian Orthopaedic Association National Joint Replacement Registry, 2014.

[3] R. J. K. Khan, A. MacDowell, P. Crossman, and G. S. Keene, "Cemented or uncemented hemiarthroplasty for displaced intracapsular fractures of the hip—a systematic review," *Injury*, vol. 33, no. 1, pp. 13–17, 2002.

[4] J. D. Wrighton and J. E. Woodyard, "Prosthetic replacement for subcapital fractures of the femur: a comparative survey," *Injury*, vol. 2, no. 4, pp. 287–293, 1971.

[5] S. Sonne-Holm, S. Walter, and J. S. Jensen, "Moore hemiarthroplasty with and without bone cement in femoral neck fractures: a clinical controlled trial," *Acta Orthopaedica*, vol. 53, no. 6, pp. 953–956, 1982.

[6] C. Fang, K.-Y. Chiu, W.-M. Tang, and D. Fang, "Cementless total hip arthroplasty specifically designed for Asians: clinical and radiologic results at a mean of 10 years," *The Journal of Arthroplasty*, vol. 25, no. 6, pp. 873–879, 2010.

[7] P. L. Althausen, M. Lu, K. C. Thomas, S. F. Shannon, B. N. Biagi, and E. M. Boyden, "Implant standardization for hemiarthroplasty: implementation of a pricing matrix system at a level II community based trauma system," *The Journal of Arthroplasty*, vol. 29, no. 4, pp. 781–785, 2014.

[8] J.-E. Gjertsen, S. A. Lie, T. Vinje et al., "More re-operations after uncemented than cemented hemiarthroplasty used in the treatment of displaced fractures of the femoral neck: an observational study of 11,116 hemiarthroplasties from a national register," *The Journal of Bone & Joint Surgery—British Volume*, vol. 94, no. 8, pp. 1113–1119, 2012.

[9] J. Christie, R. Burnett, H. R. Potts, and A. C. H. Pell, "Echocardiography of transatrial embolism during cemented and uncemented hemiarthroplasty of the hip," *The Journal of Bone and Joint Surgery—British Volume*, vol. 76, no. 3, pp. 409–412, 1994.

[10] M. I. Parker, G. Pryor, and K. Gurusamy, "Cemented versus uncemented hemiarthroplasty for intracapsular hip fractures: a randomised controlled trial in 400 patients," *The Journal of Bone & Joint Surgery—British Volume*, vol. 92, no. 1, pp. 116–122, 2010.

[11] T.-W. Lau, C. Fang, and F. Leung, "The effectiveness of a geriatric hip fracture clinical pathway in reducing hospital and rehabilitation length of stay and improving short-term mortality rates," *Geriatric Orthopaedic Surgery & Rehabilitation*, vol. 4, no. 1, pp. 3–9, 2013.

[12] M. Caliendo and S. Kopeinig, "Some practical guidance for the implementation of propensity score matching," *Journal of Economic Surveys*, vol. 22, no. 1, pp. 31–72, 2008.

[13] T. W. Lau, C. Fang, and F. Leung, "Assessment of postoperative short-term and long-term mortality risk in Chinese geriatric patients for hip fracture using the Charlson comorbidity score," *Hong Kong Medical Journal*, vol. 22, no. 1, pp. 16–22, 2016.

[14] F. Thoemmes, "Propensityscore matching in SPSS," http://arxiv.org/abs/1201.6385.

[15] P. C. Austin, "A comparison of 12 algorithms for matching on the propensity score," *Statistics in Medicine*, vol. 33, no. 6, pp. 1057–1069, 2014.

[16] G. K. Singh and R. G. Deshmukh, "Uncemented Austin-Moore and cemented Thompson unipolar hemiarthroplasty for displaced fracture neck of femur—comparison of complications and patient satisfaction," *Injury*, vol. 37, no. 2, pp. 169–174, 2006.

[17] M. J. Parker, K. S. Gurusamy, and S. Azegami, "Arthroplasties (with and without bone cement) for proximal femoral fractures in adults," *Cochrane Database of Systematic Reviews*, no. 6, Article ID CD001706, 2010.

[18] X. Luo, S. He, Z. Li, and D. Huang, "Systematic review of cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures in older patients," *Archives of Orthopaedic and Trauma Surgery*, vol. 132, no. 4, pp. 455–463, 2012.

[19] T. Li, Q. Zhuang, X. Weng, L. Zhou, and Y. Bian, "Cemented versus uncemented hemiarthroplasty for femoral neck fractures in elderly patients: a meta-analysis," *PLoS ONE*, vol. 8, no. 7, Article ID e68903, 2013.

[20] D. Davidson, J. Pike, D. Garbuz, C. P. Duncan, and B. A. Masri, "Intraoperative periprosthetic fractures during total hip arthroplasty: evaluation and management," *The Journal of Bone & Joint Surgery—American Volume*, vol. 90, no. 9, pp. 2000–2012, 2008.

[21] C. Rogmark, A. M. Fenstad, O. Leonardsson et al., "Posterior approach and uncemented stems increases the risk of reoperation after hemiarthroplasties in elderly hip fracture patients," *Acta Orthopaedica*, vol. 85, no. 1, pp. 18–25, 2014.

[22] E. Langslet, F. Frihagen, V. Opland, J. E. Madsen, L. Nordsletten, and W. Figved, "Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: 5-year followup of a randomized trial," *Clinical Orthopaedics and Related Research*, vol. 472, no. 4, pp. 1291–1299, 2014.

[23] O. Talsnes, F. Hjelmstedt, A. H. Pripp, O. Reikerås, and O. E. Dahl, "No difference in mortality between cemented and uncemented hemiprosthesis for elderly patients with cervical hip fracture. A prospective randomized study on 334 patients over 75 years," *Archives of Orthopaedic and Trauma Surgery*, vol. 133, no. 6, pp. 805–809, 2013.

[24] J. P. Deangelis, A. Ademi, I. Staff, and C. G. Lewis, "Cemented versus uncemented hemiarthroplasty for displaced femoral neck fractures: a prospective randomized trial with early follow-up," *Journal of Orthopaedic Trauma*, vol. 26, no. 3, pp. 135–140, 2012.

[25] F. J. Thoemmes and E. S. Kim, "A systematic review of propensity score methods in the social sciences," *Multivariate Behavioral Research*, vol. 46, no. 1, pp. 90–118, 2011.

[26] A. Enocson, C. J. Hedbeck, H. Törnkvist, J. Tidermark, and L. J. Lapidus, "Unipolar versus bipolar Exeter hip hemiarthroplasty: a prospective cohort study on 830 consecutive hips in patients with femoral neck fractures," *International Orthopaedics*, vol. 36, no. 4, pp. 711–717, 2012.

[27] T. Bhattacharyya and K. J. Koval, "Unipolar versus bipolar hemiarthroplasty for femoral neck fractures: is there a difference?" *Journal of Orthopaedic Trauma*, vol. 23, no. 6, pp. 426–427, 2009.

Hindawi Publishing Corporation
BioMed Research International
Volume 2016, Article ID 4061539, 8 pages
http://dx.doi.org/10.1155/2016/4061539

Clinical Study

Demineralized Bone Matrix Add-On for Acceleration of Bone Healing in Atypical Subtrochanteric Femoral Fracture: A Consecutive Case-Control Study

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Received 21 October 2015; Revised 20 January 2016; Accepted 3 February 2016

Academic Editor: Hitendra K. Doshi

Background. Delayed union and nonunion are common complications in atypical femoral fractures (AFFs) despite having good fracture fixation. Demineralized bone matrix (DBM) is a successfully proven method for enhancing fracture healing of the long bone fracture and nonunion and should be used in AFFs. This study aimed to compare the outcome after subtrochanteric AFFs (ST-AFFs) fixation with and without DBM. *Materials and Methods*. A prospective study was conducted on 9 ST-AFFs patients using DBM (DBM group) during 2013-2014 and compared with a retrospective consecutive case series of ST-AFFs patients treated without DBM (2010–2012) (NDBM group, 9 patients). All patients were treated with the same standard guideline and followed up until fractures completely united. Postoperative outcomes were then compared. *Results*. DBM group showed a significant shorter healing time than NDBM group (28.1 ± 14.4 versus 57.9 ± 36.8 weeks, $p = 0.04$). Delayed union was found in 4 patients (44%) in DBM group compared with 7 patients (78%) in NDBM group ($p > 0.05$). No statistical difference of nonunion was demonstrated between both groups (DBM = 1 and NDBM = 2, $p > 0.05$). Neither postoperative infection nor severe local tissue reaction was found. *Conclusions*. DBM is safe and effective for accelerating the fracture healing in ST-AFFx and possibly reduces nonunion after fracture fixation. Trial registration number is TCTR20151021001.

1. Introduction

Atypical femoral fractures (AFFs) are one of the current challenging topics in orthopaedic trauma and mostly related to long-term bisphosphonates (BPs) use from prevention of fragility fracture [1, 2]. Although the exact etiology of AFFs still has not been discovered, epidemiologic studies showed that most of AFFs had delayed fracture healing problem resulting in a great risk of nonunion and implant failure [1, 2]. This is mainly because AFFs have an intrinsic poor healing capacity from severely suppressed bone turnover (SSBT) that is commonly associated with long-term bisphosphonates and steroids use [1, 2]. Moreover, many other factors, such as age, comorbid diseases, ongoing medications, and fracture location in subtrochanteric region, also contribute to the prolong fracture healing capacity and, therefore, poor postoperative outcome. In 2010, a task force of American Society of Bone and Mineral Research (ASBMR) recognized this problem by concluding the related studies and then gave a recommendation for AFFs treatment including medicinal management, such as stopping bisphosphonates and prescribing teriparatide if possible, and surgical treatment with intramedullary nail [1]. However, recent studies have still shown a high rate of complications following this treatment strategy, with 56.5% of patients having delayed union [3], and 46% of them requiring revision surgery [4]. Therefore, using local adjunctive therapy, such as bone graft (autograft or allograft) or orthobiologic agent, during the fracture fixation procedure to enrich the biological substance and cytokines in a fracture site, would be an appropriate strategy to solve this problem.

Demineralized bone matrix (DBM), one of the common orthobiologic agents, is an osteoconductive and osteoinductive allograft product, which has proven its safety and efficacy to enhance bone healing in both fracture and nonunion surgeries of the long bone [5–8]. Although autologous bone graft was considered a gold standard for biologic augmentation, using DBM has many advantages such as no limitation of quantity, more reliability in osteoinductive property than autologous bone graft taken from elderly patients in a condition with drug-induced SSBT, shorter operative time, and absolutely avoiding the risk of additional procedure and no donor-site morbidity [8, 9]. Therefore, we hypothesized that an augmentation with DBM in subtrochanteric atypical femoral fracture (ST-AFFs) would improve the fracture healing capacity and postoperative outcome.

2. Materials and Methods

2.1. Study Design and Inclusion and Exclusion Criteria. This study was a single-centered prospective cohort study in a medical university hospital, between 2013 and 2014, which was compared to a retrospective consecutive case series within the same center from the earlier 3-year period. The prospective arm (DBM group) directly followed the retrospective arm (NDBM group) when the study was initiated. The inclusion criteria were the patients who were (1) newly diagnosed as AFFs regarding to the criteria of ASBMR task force 2013 [2], (2) having the fracture located on the subtrochanter defined as the area of 5 centimeters below to the lesser trochanter, (3) aged over 55 years, and (4) having no history of previous allergy to DBM. The exclusion criteria were (1) other pathological fragility fractures such as fractures from metastasis or primary tumor or simple osteoporotic fractures apart from AFFs, (2) history of high-energy trauma such as motorcycle accident, and (3) fracture location distal to 5 cm below lesser trochanter. Prior approval was obtained from our Institutional Board Review (Protocol ID 07-58-45) and informed consent was obtained from all patients in the prospective arm group, who participated in the study, before the surgery was scheduled.

2.2. Surgical Intervention and Postoperative Protocol. After diagnosing as ST-AFFs, the patients were admitted to the orthopaedic trauma ward for preoperative medical clearance and surgical planning. The operations were all done within 72 hours after admission. Specific preoperative workup protocol for AFFs was applied including clinical assessment and relevant investigations [10]. Clinical assessment included history taking of mechanism of falling, prodromal pain, associated comorbid illnesses, duration of bisphosphonate use, and risk factors for other metabolic bone diseases such as hypothyroid, chronic steroid usage, and renal failure. Relevant investigations included laboratory workup for metabolic bone disease, bone mass density assessment, radiographs of both femurs, and bone scan or magnetic resonance imaging if incomplete fracture was suspected on the contralateral side [10]. The surgery was all performed by one of the teams of experienced orthopaedic trauma surgeons (Noratep Kulachote, Paphon Sa-ngasoongsong, and Norachart Sirisreetreerux), under general or spinal anesthesia based on anesthesiologist decision. Before the introduction of this study, our treatment guideline for displaced ST-AFFs followed the recommendations from ASBMR task force 2010 [1] which indicated stopping bisphosphonate immediately after diagnosis and stabilizing fracture with full-length intramedullary nail. The fracture was reduced by mini-open and clamp-assisted reduction technique [11] in lateral decubitus position on a radiolucent operative table [12] and fixed with a standard long cephalomedullary nail with 2 distal interlocking screws. Neither bone grafting nor local orthobiologic agent was added. After the study protocol introduction, the fracture was treated with the same surgical technique and using the same implant, but 1-2 mL of DBM (DBX®, Synthes, USA) was filled into the fracture site depending on the extent of intraoperative fracture gap. All surgical wounds were closed without any drain in order to preserve DBM and hematoma that surrounded fracture site.

Postoperative care and rehabilitation were managed by the same protocol. Postoperative pain was controlled by pain medications except nonsteroidal inflammatory drugs (NSAIDs) in order to avoid delay in bone healing [13]. Cold pack was applied on the fracture site every 4 hours for one day. Prophylactic intravenous antibiotic was administered for 24 hours. Sutures were removed two weeks postoperatively. Intermittent pneumatic pump was applied on both legs. Active ankle, knee, and hip motions were advised to prevent venous thromboembolism. The patients were allowed to have partial weight bearing as tolerated on the injured leg with gait aids a few days after the operation, followed by full weight bearing when the fracture healing was demonstrated on the follow-up radiographs. Daily 20 mcg subcutaneous injection of teriparatide was prescribed postoperatively for 6 months. If the patients refused injection or had the contraindication or precaution for teriparatide (such as drug hypersensitivity, history of skeletal malignancy or bone metastasis, metabolic bone disease other than osteoporosis, history of teriparatide use more than 2 year, hypercalcemic disorder, urolithiasis and hypercalciuria, and having possible drug interaction such as digoxin, hydrochlorothiazide, and furosemide), strontium ranelate was prescribed instead. However, if the patient had severe renal impairment, such as end-stage renal disease, no anabolic treatment was given. The radiographs were taken intervals every 4–6 weeks to check for the fracture healing progression. All patients were followed until the fracture completely united.

2.3. Data Collection and Outcome Measurement. Demographic data such as age, gender, weight, height, the side of injury, and comorbid disease were collected. Body mass index (BMI) was then calculated from weight and height. Concurrent medications that were associated with AFFs (such as bisphosphonates, statins, steroids, and proton pump inhibitors) and the duration of bisphosphonate exposure were also recorded. Preoperative laboratory data, such as

Table 1: Preoperative patients' characteristics.

	NDBM group ($n = 9$)	DBM group ($n = 9$)	p value
Age, year^{+}	70 ± 7	63 ± 8	0.08
Female gender$^{■}$	9 (100)	8 (89)	1.00
Fracture on right side$^{■}$	4 (44)	6 (67)	0.64
BMI, kg/m^{2+}	22.4 ± 2.4	24.1 ± 3.2	0.22
Comorbid diseases$^{■}$			
Rheumatoid arthritis	0 (0)	2 (22)	0.47
Diabetes	2 (22)	1 (11)	1.00
Renal disease	1 (11)	2 (22)	1.00
Medications used$^{■}$			
BPs	8 (89)	9 (100)	1.00
Statin	4 (44)	4 (44)	1.00
Steroids	1 (11)	3 (33)	0.58
PPIs	4 (44)	3 (33)	0.62
Duration of BPs before fracture, year^{+}	8.9 ± 2.9[a]	7.6 ± 3.9	0.41
Preoperative laboratory values^{+}			
Hb, g/dL	11.7 ± 1.4	12.0 ± 1.8	0.72
Albumin, g/L	37.5 ± 2.6	33.1 ± 7.4	0.14
CrCl, mL/minute/1.73 m^{3}	68.4 ± 26.8	76.0 ± 31.8	0.59
Calcium, mg/dL	9.2 ± 0.7	8.6 ± 0.6	0.07
Inorganic phosphate, mg/dL	3.4 ± 0.3	3.3 ± 0.7	0.73
25-OH vitamin D, ng/mL	28.8 ± 9.3	27.8 ± 11.6	0.88
Total P1NP, ng/mL	46.4 ± 60.8	55.0 ± 64.8	0.8
β-cross laps, ng/mL	0.24 ± 0.21	0.23 ± 0.19	0.99
PTH, pg/mL	50.5 ± 47.9	51.2 ± 22.8	0.97
Follow-up time, week^{+}	125 ± 60	72 ± 40	**0.04***

$^{+}$Value presented as mean ± standard deviation. $^{■}$Value presented as number of patients (percentage).
BMI: body mass index; BPs: bisphosphonates; PPIs: proton pump inhibitors; Hb: hemoglobin.
CrCl: creatinine clearance; P1NP: procollagen type 1 N-terminal propeptide.
CTX: collagen type 1 C-telopeptide; PTH: parathyroid hormone.
[a]Calculated only from the patients receiving BPs. *Significant value as $p < 0.05$.

hemoglobin (Hb), albumin, creatinine clearance, calcium, inorganic phosphate, total 25-OH vitamin D, total procollagen type 1 N-terminal propeptide (P1NP), collagen type 1 C-telopeptide (β-cross laps), and parathyroid hormone level (PTH), were recorded.

Postoperative radiographs were evaluated by 3 authors (Noratep Kulachote, Paphon Sa-ngasoongsong, and Praman Fuangfa) for fracture reduction alignment, neck-shaft angle of both normal and injured sides, and status of fracture union. Radiographic healing was defined as bridging callus on three out of four cortices as determined on the anteroposterior and lateral views [14]. Fracture healing after 6 months was defined as delayed union [15], while fractures without increased callus formation after 6 months on follow-up radiographs or those who had hardware failure were defined as nonunion [14].

Primary outcome was the healing time calculated from the duration between the first operative date and the time of diagnosis of fracture healing on radiographs. Secondary outcomes were the status of union, delayed union, and nonunion.

2.4. Statistical Analysis. Statistical analysis was performed using Statistical Package of Social Sciences (SPSS) software version 18.0. Continuous data were presented as mean and standard deviation and compared with t-test. Categorical data were presented as proportion and compared with Fisher's exact test or Chi-square test as appropriate. Significant difference was considered if p value < 0.05.

3. Result

A total of 18 patients (17 females and one male) were enrolled into this study (nine patients in each of NDBM and DBM group). Demographic data and clinical results were shown on Tables 1 and 2. The average age was 67 years (range 56–81 years). The mean BMI was 23.2 kg/m^2 (range 18.2–28.7 kg/m^2). Three patients had diabetic mellitus (2 in NDBM group and 1 in DBM group) and two patients had rheumatoid arthritis (both in DBM group). Seventeen patients (94%) had history of bisphosphonate use and the mean duration of the bisphosphonate exposure was 8.2 years (range 1.5–15 years). One patient (6%, number 8), who did not receive bisphosphonate, had long-term steroids due to rheumatoid arthritis. There was no significant difference between age, gender, the side of injury, BMI, comorbid disease, ongoing

Table 2: Details of treatment and outcome on each patient.

Case number	Gender	Age (year)	Side	Comorbid diseases	DBM (mL)	Duration of BPs (year)	Indication of BPs	Anabolic treatment	Healing time (week)	Delayed union	Nonunion	Reoperation details
1	F	59	Rt	HLP	—	5	Osteopenia	STR	50.0	Yes	No	
2	F	78	Lt	HT, HLP	—	11	PMO	STR	39.4	Yes	No	
3	F	75	Rt	DM, HT, HLP	—	8	PMO	TPTD	112.3	Yes	Yes	ORIF with PF-LCP and IBG + NVFBG
4	F	67	Rt	HT, paroxysmal SVT	—	7	PMO	TPTD	43.1	Yes	No	
5	F	81	Lt	CKD, HT, HLP, ET	—	14	PMO	TPTD	88.1	Yes	No	
6	F	64	Lt	—	—	11	PMO	TPTD	13.7	No	No	
7	F	75	Rt	—	—	8	Osteopenia	STR	39.6	Yes	No	
8	F	66	Lt	Myasthenia gravis, HT	—	—	—	—	23.4	No	No	
9	F	65	Lt	HT, DLP, DM, asthma	—	7	PMO	TPTD	111.4	Yes	Yes	ORIF with ABP and DBM
10	M	59	Rt	Ventricular schwannoma	2	15	Osteoporosis	TPTD	52.3	Yes	No	
11	F	56	Rt	SLE, ESRD, DLP, HT, AVN	2	5	AVN	—	34.9	Yes	No	
12	F	66	Lt	ESRD s/p KT, HT, cardiomyopathy	1	1.5	PMO, GIOP	STR	13.9	No	No	
13	F	56	Rt	HT, OSA	1	6	PMO	TPTD	17.1	No	No	
14	F	64	Lt	DM, HT, RA, DLP	1	9	Osteopenia	TPTD	48.7	Yes	Yes	ORIF with ABP and DBM
15	F	64	Rt	DLP	2	10	PMO	TPTD	27.0	Yes	No	
16	F	79	Lt	HT, DLP	2	5	PMO	STR	19.4	No	No	
17	F	70	Rt	HT, DLP, peptic ulcer	1	7	PMO	TPTD	26.1	No	No	
18	F	57	Rt	—	1	10	PMO	TPTD	13.9	No	No	

HLP: hyperlipidemia; HT: hypertension; DM: diabetes; SVT: supraventricular tachycardia; CKD: chronic kidney disease.
ET: essential thrombocytosis; SLE: systemic lupus nephritis; ESRD: end-stage renal disease; AVNFH: avascular necrosis.
s/p KT: status postoperative kidney transplant; OSA: obstructive sleep apnea; RA: rheumatoid arthritis.
DBM: demineralized bone matrix; PMO: postmenopausal osteoporosis; GIOP: glucocorticoid induced osteoporosis.
STR: strontium ranelate; TPTD: teriparatide; ORIF: open reduction and internal fixation; PF-LCP: proximal femur locking compression plate.
ABP: angle blade plate; IBG: iliac bone graft; NVFBG: nonvascularized fibular bone graft.

Table 3: Postoperative outcomes.

	NDBM group ($n = 9$)	DBM group ($n = 9$)	p value
Postoperative alignment[+]			
Coronal plane[b]	−8.0 ± 7.1	−4.2 ± 3.8	0.18
Sagittal plane[c]	−5.2 ± 12.2	−6.3 ± 4.9	0.8
Neck-shaft angle[+]			
Fracture side	131 ± 8	132 ± 4	0.88
Normal side	136 ± 5	133 ± 5	0.25
Postoperative anabolic agent			
Teriparatide	5	6	1.00
Strontium ranelate	3	2	
Healing time, week[+]	57.9 ± 36.8	28.1 ± 14.4	**0.04**[*]
Received teriparatide	73.7 ± 43.7	30.9 ± 16.1	0.09[w]
Not received teriparatide	38.1 ± 11.0	22.7 ± 10.9	0.13
Nonunion[■]	2 (2 : 0)	1 (1 : 0)	1.00
Delayed union[■]	7 (4 : 3)	4 (3 : 1)	0.33

[+]Value presented as mean ± standard deviation.
[■]Value presented as number of patients (received postoperative teriparatide: strontium ranelate).
[b]Negative and positive value meant varus and valgus angulation, respectively.
[c]Negative and positive value meant anterior and posterior angulation, respectively.
[*]Significant value as $p < 0.05$.
[w]Calculated from t-test with a correction of unequal variance (Welch test).

medications, duration of bisphosphonate exposure, and preoperative laboratory values between both groups ($p > 0.05$ all). However, the follow-up time was significantly longer in the NDBM group compared with the DBM group ($p = 0.04$).

Postoperative outcomes were shown in Table 3. There was no significant difference in postoperative fracture reduction alignment and neck-shaft angle between both groups ($p >$ 0.05 all). Postoperative teriparatide injection was given in 5 patients in non-DBM group and 6 patients in DBM group. Strontium ranelate was given in 3 patients in non-DBM group and 2 patients in DBM group. One patient in each group did not receive anabolic agent postoperatively. There was no significant difference between the distribution of postoperative medication in both groups ($p = 1.00$). The DBM group showed a significant shorter healing time compared with the NDBM group (28.1 ± 14.4 weeks versus 57.9 ± 36.8 weeks, $p = 0.04$). Subgroup analysis showed that the DBM group with and without postoperative teriparatide had nonsignificantly shorter healing time compared to the NDBM group ($p = 0.09$ and 0.13, resp.). Case examples from NDBM group (case number 4 from Table 2) and from DBM group (case number 16 from Table 2) were shown in Figures 1 and 2, respectively. Delayed union occurred in 4 patients (44%) in the DBM group and 7 patients (78%) in the NDBM group ($p = 0.33$). Atrophic or oligotrophic nonunion was developed in 2 patients (22%) in the NDBM group and one patient (11%) in the DBM group ($p = 1.00$). All patients with nonunion were successfully treated with nail removal and open reduction and internal fixation with either 95-degree angle blade plate or proximal femur locking compression plate and augmentation with autologous bone graft and DBM. Neither surgical site infection nor severe local tissue reaction was found in this study.

4. Discussion

Management of atypical femoral fractures (AFFs) is a challenging task in orthopaedic trauma, mainly due to poor fracture healing property related to severely suppressed bone turnover [1, 2]. Additionally, many contributing factors, such as age, comorbid illnesses, concurrent medications, and fracture location in subtrochanter area, may negatively affect the fracture healing and result in delayed union, nonunion, and implant failure. Moreover, the AFFs patients are commonly associated with long-term bisphosphonates or steroids use that directly prolonged the fracture healing and remodeling process, especially when direct bone healing process was expected (such as the plate and screw fixation). Therefore, ASBMR task force had recommended the specific treatment guideline for AFFs including appropriate medical management and surgical fixation with an intramedullary nail [1]. However, recent studies have demonstrated that this strategy still resulted in a high rate of delay union and reoperation due to fracture healing complications [3, 4, 15, 16]. Therefore, using local adjunctive therapy with orthobiologic agent, during the fracture fixation surgery to enrich the biological substances and cytokines in fracture site, should be a key to success to solve this problem. Unfortunately, the autologous bone graft, a gold standard biologic agent, would not be an appropriate choice in AFFs patients due to the limitation of quantity, unreliable osteoinductive property from prolonged drug-induced osteoclastic suppression, need for additional operative procedure, and risk of donor-site morbidity [8, 9]. On the other hand, demineralized bone matrix (DBM), a common orthobiologic agent, which had demonstrated its safety and efficacy in treatment of both fracture and nonunion of the long bone surgeries [5–8], should be useful in enhancing bone healing in AFFs. Therefore, this study

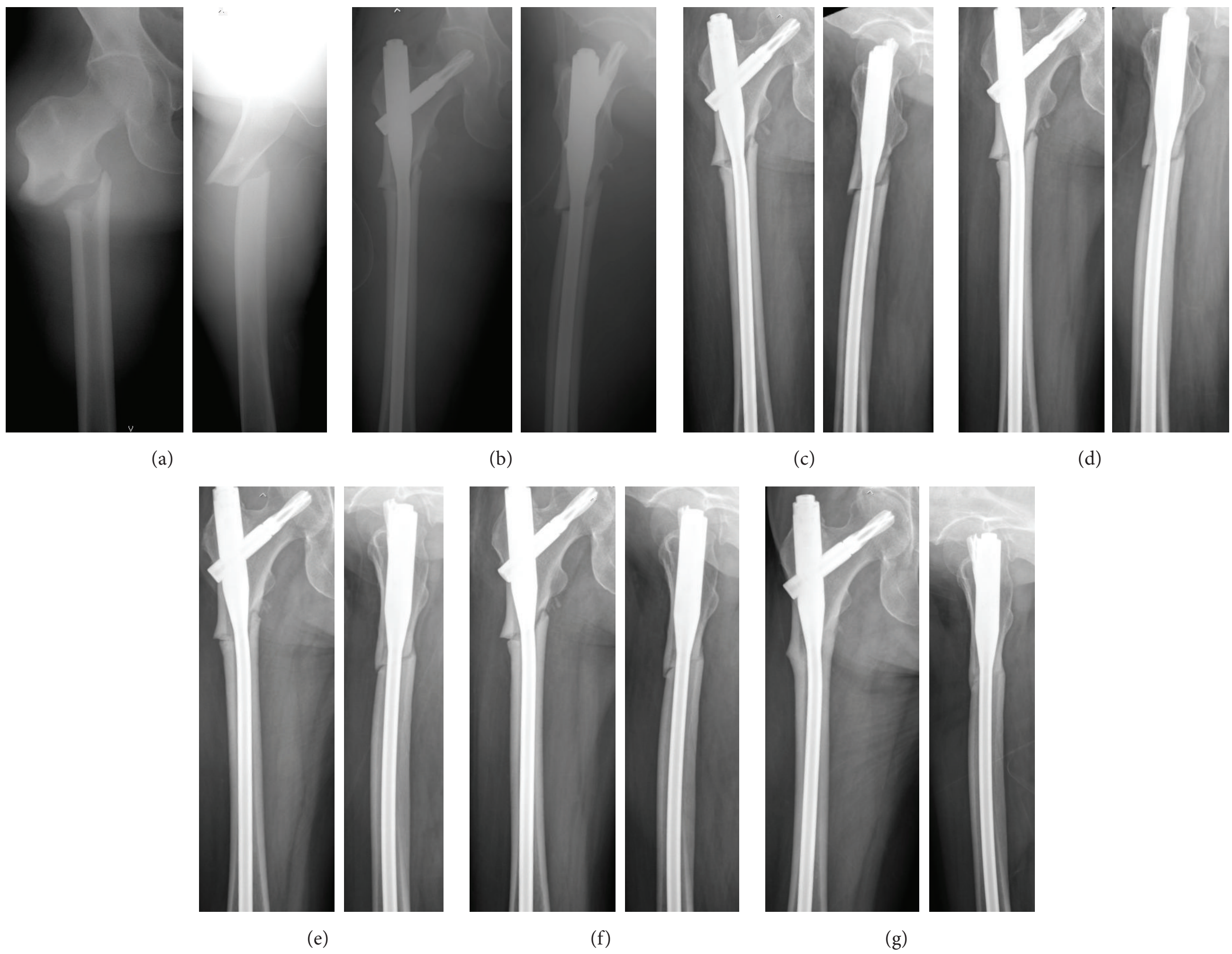
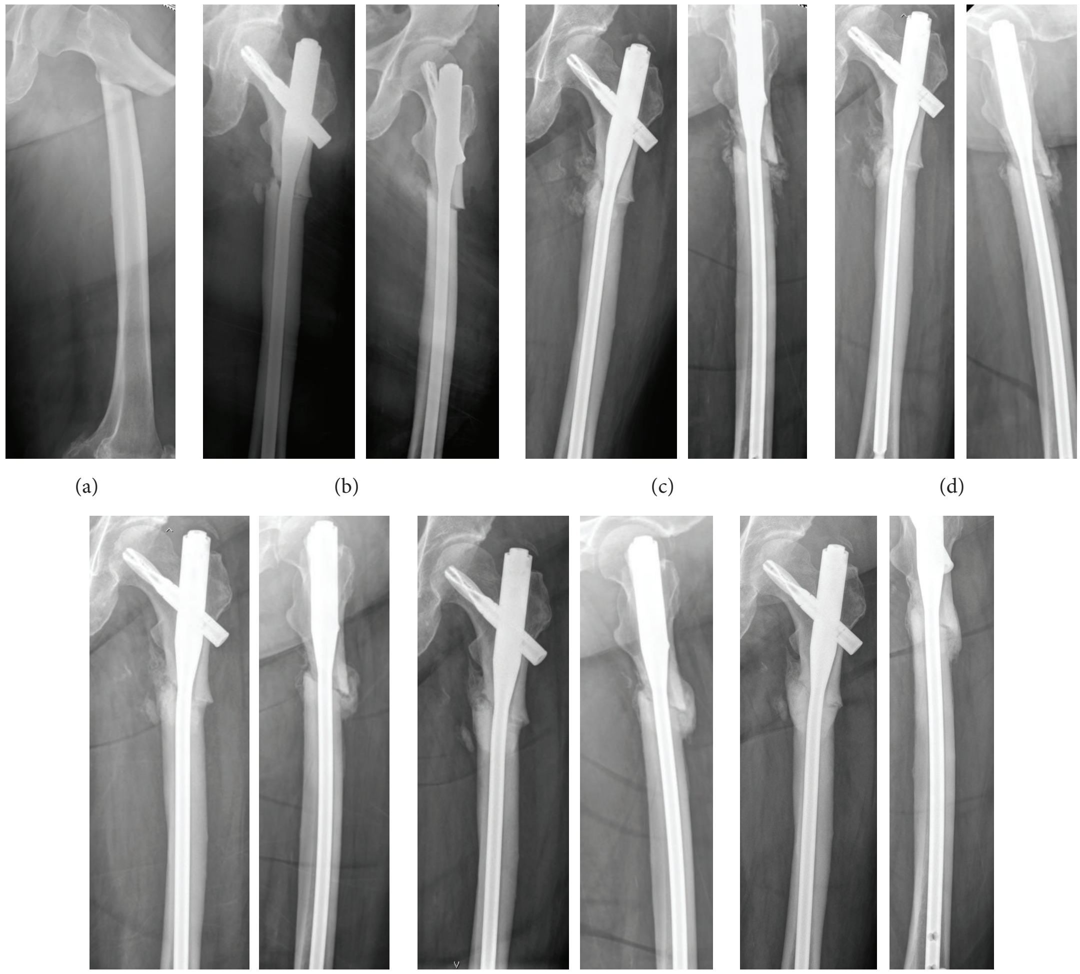


Figure 1: Radiographs from case examples with atypical subtrochanteric femoral fracture (ST-AFF) treated without using demineralized bone matrix (NDBM group). Preoperative (a) and immediate postoperative (b) radiographs showed ST-AFF treated with cephalomedullary nail. Follow-up radiographs after 2 months (c), 4 months (d), and 6 months (e) showed very minimal callus formation. However, the fracture still had healing progression after 8 months (f) and finally completely united after 14 months postoperatively (g).

aimed to compare the outcome of subtrochanteric atypical femoral fracture (ST-AFFs) treated with a standard guideline with and without using demineralized bone matrix (DBM), as an add-on orthobiologic agent, in terms of the healing time and fracture healing complication.

The result from this study, though, showed an incidence of delayed union after treatment of ST-AFFs by a standard guideline as 78% (7 patients in NDBM group), which was higher than previous studies (43–57%) [3, 4, 15, 16]. This may be due to the fact that our study population focused only on subtrochanteric fractures which typically have poorer healing capacity than diaphyseal fractures due to a relative lack of blood supply and higher stress load on the fracture site, resulting in a high incidence of delayed union in this series. However, the most important finding in this study was that we could demonstrated a significant improvement in fracture healing time in the DBM group compared to the NDBM group ($p = 0.04$), which implied that the add-on DBM resulted in a significantly increased fracture healing capacity by improving osteogenic and osteoinductive properties by enriching the biological substances and cytokines and, therefore, promoting the bone generation in AFFs after treatment with intramedullary nailing. However, we could not demonstrate the significant improvement on the incidence of delayed union (44% in DBM group versus 77% in NDBM group, $p = 0.33$) and nonunion (11% in DBM group versus 22% in NDBM group, $p = 1.00$). This could be explained by the effect of small sample size and confounding factors which affected the fracture healing such as age, comorbid illness, and postoperative medications [15, 17].

Our study also had several limitations. First, we had a small number of patients due to the uncommon presentation of ST-AFFs. Second, there were no comparative data of the non-AFF treatment that needs teriparatide or strontium supplement because the fracture healing potential in those patients was still good, and we also did not use any anabolic



(a) (b) (c) (d) (e) (f) (g)

Figure 2: Radiographs from case examples with atypical subtrochanteric femoral fracture (ST-AFF) treated using demineralized bone matrix (DBM group). Preoperative (a) and immediate postoperative (b) radiographs showed ST-AFF treated with cephalomedullary nail. Follow-up radiographs after 3-month (c) and 4.5-month (d) period demonstrated the appropriate callus formation on anterior, posterior, and medial cortex and therefore was considered healed fracture. The fracture remodeling without complication was confirmed on 6-month, 8-month, and 11-month radiographs postoperatively.

medications to enhance bone healing in our routine practice. Third, this was a case-controlled study in which we could not control confounding factors that might affect the fracture healing. Thus, further studies, such as randomized controlled trial with a larger number of AFFs patients, are required to demonstrate the efficacy of this technique. However, to our knowledge, this study was the first study that used the DBM as an initial treatment in AFFs, and we believe that the local DBM augmentation would provide the better surgical outcomes and quality of life for the AFFs patients suffering from this fracture.

In conclusion, local DBM augmentation on the treatment of atypical subtrochanter femoral fracture is an interesting option. It is safe and effective in improving the fracture healing time and possibly reducing the fracture healing complication. Further researches are required to reveal its true efficacy and effectiveness in the treatment of AFFs.

Conflict of Interests

All of the authors declare that they have no conflict of interests.

Acknowledgment

The authors wish to thank Department of Orthopedics, Faculty of Medicine Ramathibodi Hospital, Mahidol University, for all of the kind help and permission to carry out this study.

References

[1] E. Shane, D. Burr, P. R. Ebeling et al., "Atypical subtrochanteric and diaphyseal femoral fractures: report of a task force of the American Society for Bone and Mineral Research," *Journal of Bone and Mineral Research*, vol. 25, no. 11, pp. 2267–2294, 2010.

[2] E. Shane, D. Burr, B. Abrahamsen et al., "Atypical subtrochanteric and diaphyseal femoral fractures: second report of a task force of the American society for bone and mineral research," *Journal of Bone and Mineral Research*, vol. 29, no. 1, pp. 1–23, 2014.

[3] J. S. Kang, Y. Y. Won, J. O. Kim et al., "Atypical femoral fractures after anti-osteoporotic medication: a Korean multicenter study," *International Orthopaedics*, vol. 38, no. 6, pp. 1247–1253, 2014.

[4] Y. A. Weil, G. Rivkin, O. Safran, M. Liebergall, and A. J. Foldes, "The outcome of surgically treated femur fractures associated with long-term bisphosphonate use," *Journal of Trauma—Injury, Infection and Critical Care*, vol. 71, no. 1, pp. 186–190, 2011.

[5] R. W. Lindsey, G. W. Wood, K. K. Sadasivian, H. A. Stubbs, and J. E. Block, "Grafting long bone fractures with demineralized bone matrix putty enriched with bone marrow: pilot findings," *Orthopedics*, vol. 29, no. 10, pp. 939–941, 2006.

[6] S. Cheung, K. Westerheide, and B. Ziran, "Efficacy of contained metaphyseal and periarticular defects treated with two different demineralized bone matrix allografts," *International Orthopaedics*, vol. 27, no. 1, pp. 56–59, 2003.

[7] B. Ziran, S. Cheung, W. Smith, and K. Westerheide, "Comparative efficacy of 2 different demineralized bone matrix allografts in treating long-bone nonunions in heavy tobacco smokers," *The American Journal of Orthopedics*, vol. 34, no. 7, pp. 329–332, 2005.

[8] O. Pieske, A. Wittmann, J. Zaspel et al., "Autologous bone graft versus demineralized bone matrix in internal fixation of ununited long bones," *Journal of Trauma Management & Outcomes*, vol. 3, article 11, 2009.

[9] G. I. Drosos, P. Touzopoulos, A. Ververidis, K. Tilkeridis, and K. Kazakos, "Use of demineralized bone matrix in the extremities," *World Journal of Orthopedics*, vol. 6, no. 2, pp. 269–277, 2015.

[10] S. De Das, T. Setiobudi, L. Shen, and S. De Das, "A rational approach to management of alendronate-related subtrochanteric fractures," *The Journal of Bone and Joint Surgery—British Volume*, vol. 92, no. 5, pp. 679–686, 2010.

[11] A. Afsari, F. Liporace, E. Lindvall, A. Infante Jr., H. C. Sagi, and G. J. Haidukewych, "Clamp-assisted reduction of high subtrochanteric fractures of the femur: surgical technique," *Journal of Bone and Joint Surgery Series: A*, vol. 92, supplement 1, part 2, pp. 217–225, 2010.

[12] J. A. Bishop and E. K. Rodriguez, "Closed intramedullary nailing of the femur in the lateral decubitus position," *The Journal of Trauma*, vol. 68, no. 1, pp. 231–235, 2010.

[13] E. R. Dodwell, J. G. Latorre, E. Parisini et al., "NSAID exposure and risk of nonunion: a meta-analysis of case-control and cohort studies," *Calcified Tissue International*, vol. 87, no. 3, pp. 193–202, 2010.

[14] J. T. Riehl, K. J. Koval, J. R. Langford, M. W. Munro, S. J. Kupiszewski, and G. J. Haidukewych, "Intramedullary nailing of subtrochanteric fractures—does malreduction matter?" *Bulletin of the Hospital for Joint Disease*, vol. 72, no. 2, pp. 159–163, 2014.

[15] N. Miyakoshi, T. Aizawa, S. Sasaki et al., "Healing of bisphosphonate-associated atypical femoral fractures in patients with osteoporosis: a comparison between treatment with and without teriparatide," *Journal of Bone and Mineral Metabolism*, vol. 33, no. 5, pp. 553–559, 2015.

[16] K. A. Egol, J. H. Park, Z. S. Rosenberg, V. Peck, and N. C. Tejwani, "Healing delayed but generally reliable after bisphosphonate-associated complete femur fractures treated with IM nails," *Clinical Orthopaedics and Related Research*, vol. 472, no. 9, pp. 2728–2734, 2014.

[17] M. S. Gaston and A. H. R. W. Simpson, "Inhibition of fracture healing," *Journal of Bone and Joint Surgery Series: B*, vol. 89, no. 12, pp. 1553–1560, 2007.

Hindawi Publishing Corporation
BioMed Research International
Volume 2016, Article ID 4175092, 8 pages
http://dx.doi.org/10.1155/2016/4175092

Research Article

Increased Fracture Collapse after Intertrochanteric Fractures Treated by the Dynamic Hip Screw Adversely Affects Walking Ability but Not Survival

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Received 12 October 2015; Accepted 11 January 2016

Academic Editor: Nikolaos K. Kanakaris

In osteoporotic hip fractures, fracture collapse is deliberately allowed by commonly used implants to improve dynamic contact and healing. The muscle lever arm is, however, compromised by shortening. We evaluated a cohort of 361 patients with AO/OTA 31.A1 or 31.A2 intertrochanteric fracture treated by the dynamic hip screw (DHS) who had a minimal follow-up of 3 months and an average follow-up of 14.6 months and long term survival data. The amount of fracture collapse and shortening due to sliding of the DHS was determined at the latest follow-up and graded as minimal (<1 cm), moderate (1-2 cm), or severe (>2 cm). With increased severity of collapse, more patients were unable to maintain their premorbid walking function (minimal collapse = 34.2%, moderate = 33.3%, severe = 62.8%, and $p = 0.028$). Based on ordinal regression of risk factors, increased fracture collapse was significantly and independently related to increasing age ($p = 0.037$), female sex ($p = 0.024$), A2 fracture class ($p = 0.010$), increased operative duration ($p = 0.011$), poor reduction quality ($p = 0.000$), and suboptimal tip-apex distance of >25 mm ($p = 0.050$). Patients who had better outcome in terms of walking function were independently predicted by younger age ($p = 0.036$), higher MMSE marks ($p = 0.000$), higher MBI marks ($p = 0.010$), better premorbid walking status ($p = 0.000$), less fracture collapse ($p = 0.011$), and optimal lag screw position in centre-centre or centre-inferior position ($p = 0.020$). According to Kaplan-Meier analysis, fracture collapse had no association with mortality from 2.4 to 7.6 years after surgery. In conclusion, increased fracture collapse after fixation of geriatric intertrochanteric fractures adversely affected walking but not survival.

1. Introduction

Implants designed for fixation of osteoporotic hip fracture typically allow controlled sliding and collapse to improve bony contact and healing [1]. The dynamic hip screw (DHS) is one of the most widely used and successful implants for the treatment of stable intertrochanteric fractures with such design concept [2, 3]. Conversely, statically locked implants that aim at static fixation have yielded unacceptably high rate of failures for routine osteoporotic hip fractures because of the lack of dynamic compression and a lack of technical tolerance [4, 5]. Cephalomedullary fixation devices [6] and DHS with trochanter stabilizing plate [7] are effective means in preventing excessive collapse in unstable fractures (such as the AO/OTA type 31.A3 [8, 9]) but still much debated for routing use in more stable and intermediate patterns (such as types 31.A1 and A2).

Fracture collapse is sometimes associated with fixation failure [10] and believed to impair the hip abduction lever arm [11]. Researchers have pointed out that, for intracapsular hip fractures, increased fracture collapse accounted for poorer functional recovery [12, 13]. In young patients with trochanteric fractures, previous studies have shown that significant shortening of more than 2 cm is associated with

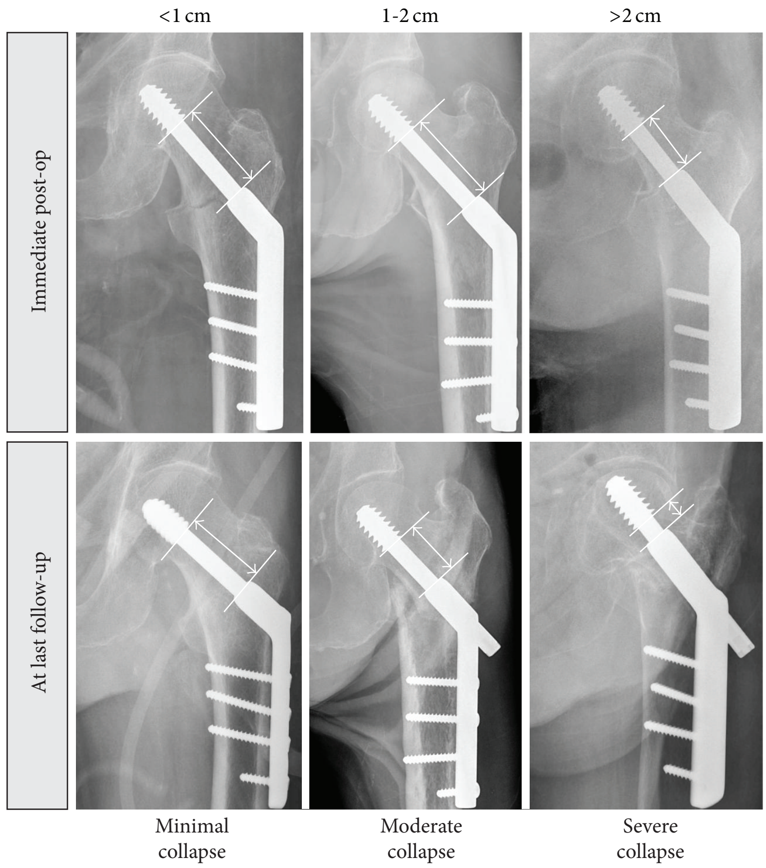

Figure 1: Grading of severity of fracture collapse and shortening.

impaired functional outcome [14] and previous studies have shown that DHS are associated with more pronounced shortening than cephalomedullary devices in young bone [14]. Currently, it has not been clearly studied whether collapse also adversely affects functional and survival outcomes for elderlies with trochanteric hip fractures.

Our objective was to test the hypothesis on whether patients with increasing degree of fracture collapse and shortening after DHS had impaired walking and increased incidence of adverse events. We carried out a secondary analysis of a consecutive prospective cohort of patients with trochanteric fractures treated with two similar DHS designs [15].

2. Patients and Methods

We reviewed a consecutive cohort of 433 patients with AO/OTA [8, 9] 31.A1 and 31.A2 fractures operated from 2007 to 2012 with DHS lag screws or DHS blades (both from formerly Synthes, Oberdorf, Switzerland). Only the cephalic portion of the implant differed and both were mounted on a standard nonlocked four-hole DHS slide plate. All included patients were over 50 years and patients with pathological fractures were excluded. Our hip fracture pathway [16] mandated surgical treatment as soon as possible unless the patient was medically unfit. A standard lateral subvastus approach was used for all patients on a traction table by closed or optional open assisted reduction. Patients followed a multidisciplinary rehabilitation protocol and were allowed immediate full weight bearing exercise. Upon follow-up, the functional status in walking and radiographs were analysed for collapse and complications.

The degree of fracture collapse was determined by comparing the intraoperative and the latest anteroposterior radiograph. The remaining length of the lag screw or blade available for collapse was noted. The amount of collapse was determined at fracture union or at time of latest radiograph before any catastrophic mechanical failure. The degree of collapse was graded as minimal if this was not detectable when comparing the two radiographs or less than 1 cm, moderate if this was from 1 to 2 cm, and severe if this was more than 2 cm. The core diameter of the lag or the length of the side-plate barrel is used as reference dimensions to correct for the effects of magnification and rotation (see Figure 1).

Perioperative patient, fracture, and surgical variables were compared for factors associated with different degree of collapse. These included age, gender, American Anesthesia Society (ASA) score, hours from admission to surgery (more than 48 hours versus less than 48 hours), Mini Mental State Exam (MMSE) score [17], Modified Barthel Index [18] (MBI), surgeon experience (specialists with more than six years of experience versus trainees with less), and premorbid walking status. Walking status was graded as independent walker for those who did not require any assistance; assisted walkers if some degree of assistance was needed for activity of daily living; and nonfunctional walkers either if considerable assistance is needed or if the patient cannot walk at all. Implant position was defined as optimal if the fixation device was placed at the centre-centre or centre-inferior position of the femoral head; the tip-apex distance, as defined by Baumgaertner et al. [19], is optimal when less than 25 mm. Fracture reduction was defined according to Baumgaertner et al. [20] depending on the presence of a translation of more than 4 mm or varus of more than 5 degrees (good or acceptable reduction) or both (poor reduction).

The primary outcome was the best walking status achieved after rehabilitation using the same definition as the premorbid walking status. The premorbid walking grade was compared with postoperatively to determine whether there was a deterioration by one grade or more. The secondary outcomes were mortality, presence of complications including lateral wall fractures, implant migration in femoral head, cutout, side-plate pullout, nonunion, infection, and reoperations. Mortality data is recovered from the local territory wide electronic death registry, while survival is determined according to any patient attendance documented in the electronic public health care system which offers more than 90% territorial coverage.

SPSS software version 23 (IBM, Armonk NY, USA) was used for statistical analysis. The hips with collapse grades of minimal (1), moderate (2), and severe (3) degrees were designated as an ordinal variable and tested for associations. The Kruskal-Wallis test with Monte Carlo significance of 10000 random seeded samples was used for nonparametric variables and the one-way ANOVA test was used for parametric variables. Ordinal logistic regression was carried out firstly to identify independent factors which predicted increasing severity of fracture collapse and secondly to identify factors which predicted increased likelihood to walk well after rehabilitation. A p value of <0.05 was taken as statistically significant.

3. Results

3.1. Baseline Factors and Univariate Analysis. Patients who have died or were lost to follow-up before 3 months were excluded from analysis unless they were already documented to have moderate or severe degrees of fracture collapse. Out of the 433 total patients treated with a DHS, 354 patients had a radiological follow-up of at least 3 months and 7 additional patients had an earlier known moderate or severe collapse. In all, 361 patients fulfilled the analysis criteria.

Of the 361 patients, 319 (88.4%) had an X-ray taken after at least 6 months and 293 (81.2%) after at least 9 months. The mean radiological follow-up was 14.6 months. Definite survival or mortality data was recovered for 360 (99.7%) patients at the time of data analysis which was 2.4 to 7.6 years after surgery (see Table 1).

Out of the 361 patients entered for analysis, 234 had minimal collapse, 84 had moderate collapse, and 43 had severe collapse. Out of the 43 patients with severe collapse, 20 patients had complete collapse where the lag screw or blade was touching the barrel and with no possibility for further collapse. This subgroup was, however, deemed too small for further analysis under a separate rank.

Table 1: Patient selection and follow-up characteristics.

Patients and follow-up characteristics		
Total patients	%	$n = 433$
Known moderate or severe collapse before 3 months	1.6%	7
Adequate follow-up at 3 months	81.8%	354
Fulfilled analysis criteria	83.4%	361
Survival data available 2.4–7.6 years post-op	99.7%	360
Had X-ray after 6 months	88.4%	319
Had X-ray after 9 months	81.2%	293

Patients with increasing severity of collapse were significantly older (mean age for minimal collapse = 83, moderate collapse = 82.6, severe collapse = 86, and $p = 0.042$), more likely suffered from A2 fractures (minimal = 40.2%, moderate = 65.5%, severe = 67.4%, and $p = 0.000$), and more likely had suboptimal tip-apex distance of more than 25 mm (minimal = 0%, moderate = 6%, severe = 0%, and $p = 0.002$) and poor reduction (minimal = 0.9%, moderate = 7.1%, severe = 18.6%, and $p = 0.000$) (see Table 2).

A number of poor outcomes were significantly associated with the severity of collapse, including nonfunctional walking status after rehabilitation (minimal collapse = 20.5%, moderate = 25%, severe = 34.9%, and $p = 0.016$), inability to maintain premorbid walking function (minimal collapse = 34.2%, moderate = 33.3%, severe = 62.8%, and $p = 0.028$), and reoperations (minimal = 0.9%, moderate = 2.4%, severe = 11.6%, and $p = 0.002$).

A number of adverse radiological features or complications were more common in those with increasing severity of collapse, including lateral wall fractures (minimal = 2.1%, moderate = 21.4%, severe = 55.8%, and $p = 0.000$), implant migration in the femoral head (minimal = 0.4%, moderate = 4.8%, severe = 11.6%, and $p = 0.001$), hip joint cutouts (minimal = 0%, moderate = 2.4%, severe = 11.6%, and $p = 0.000$), and nonunions (minimal = 0%, moderate = 1.2%, severe = 16.3%, and $p = 0.000$).

The mean survival of patients with minimal collapse was 916 days (95% CI: 807–1025), with moderate collapse it was 1025 days (95% CI: 794–1256), and with severe collapse it was 944 days (95% CI: 721–1196). Patients with increasing severity of collapse had no difference in survival up to 7.6 years after surgery in Kaplan-Meier survival analysis (log-rank test, $p = 0.503$) (see Figure 2).

3.2. Multivariate Analysis. Based on ordinal regression, the independent risk factors for increased collapse were increasing age ($p = 0.037$), female sex ($p = 0.024$), 31.A2 fracture class ($p = 0.010$), increased operative duration ($p = 0.011$), poor reduction quality ($p = 0.000$), and suboptimal tip-apex distance of >25 mm ($p = 0.050$) (see Table 3).

Ordinal regression also showed that significant factors which independently predicted better functional waking

Table 2: Differences in baseline and outcome variables in relation to increasing severity of collapse.

Amount of collapse	Minimal %/mean	Minimal $n = 234$	Moderate %/mean	Moderate $n = 84$	Severe %/mean	Severe $n = 43$	p value
Baseline and surgical variables							
Age at operation	83	(SD = 0.75)	82.6	(SD = 0.85)	86	(SD = 0.62)	**0.042***
Female versus males	59.8%	140	71.4%	60	74.4%	32	0.057
31.A2 versus A1	40.2%	94	65.5%	55	67.4%	29	**0.000**
Screw versus blade fixation	54.7%	128	58.3%	49	46.5%	20	0.461
Premorbid nonfunctional walker	6.8%	16	9.5%	8	2.3%	1	
Premorbid assisted walker	10.7%	25	13.1%	11	14.0%	6	0.531
Premorbid independent walker	81.2%	190	77.4%	65	83.7%	36	
Operation delayed more than 2 days after admission	10.3%	24	6.0%	5	2.3%	1	0.143
MMSE score	15.9	(SD = 7.4)	16.1	(SD = 7.7)	15.9	(SD = 7.4)	0.984*
Modified Barthel Index	85.3	(SD = 22.4)	84.4	(SD = 25.1)	83.4	(SD = 23.9)	0.890*
ASA score 3 or above	62.0%	145	63.1%	53	58.1%	25	0.862
Operated by trainees (<6 years of experience)	31.6%	74	29.8%	25	30.2%	13	0.941
Operative time	41.5 mins	(SD = 16.3)	43.6 mins	(SD = 18.6)	47.8 mins	(SD = 21.3)	0.084*
Suboptimal centre-centre or centre-inferior lag screw position	27.4%	64	42.9%	36	39.5%	17	**0.019**
Suboptimal tip-apex distance > 25 mm	0.0%	0	6.0%	5	0.0%	0	**0.002**
Poor reduction (>4 mm translation and 5 degrees varus)	0.9%	2	7.1%	6	18.6%	8	
Acceptable reduction (>4 mm translation or 5 degrees varus)	19.7%	46	42.9%	36	30.2%	13	**0.000**
Good reduction (<4 mm translation and <5 degrees varus)	79.5%	186	50.0%	42	51.2%	22	
Perfect reduction (<2 mm translation and no varus)	59.4%	139	35.7%	30	30.2%	13	**0.000**
Outcomes							
Walking function							
Nonfunctional walker	20.5%	48	25.0%	21	34.9%	15	
Assisted walker	26.9%	63	22.6%	19	34.9%	15	**0.016**
Independent walker	52.6%	123	52.4%	44	27.9%	12	
Unable to maintain walking function	34.2%	80	33.3%	28	62.8%	27	**0.028**
Cumulative mortality							
Died at 6 months	2.1%	5	1.2%	1	2.3%	1	0.880
Died at 1 year	8.5%	20	8.3%	7	2.3%	1	0.377
Died at 2 years	22.2%	52	19.0%	16	16.3%	7	0.628
Complications							
Lateral wall fractures	2.1%	5	21.4%	18	55.8%	24	**0.000**
Any mechanical failure	0.4%	1	7.1%	6	23.3%	10	**0.000**
Implant migration in femoral head	0.4%	1	4.8%	4	11.6%	5	**0.001**
Hip joint penetration and cutout	0.0%	0	2.4%	2	11.6%	5	**0.000**
Side plate pullout	0.0%	0	0.0%	0	2.3%	1	0.111
Nonunion	0.0%	0	1.2%	1	16.3%	7	**0.000**
Infection	0.4%	1	0.0%	0	4.7%	2	0.053
Reoperations	0.9%	2	2.4%	2	11.6%	5	**0.002**

Kruskal-Wallis test with Monte Carlo significance for nonparametric variables.
*One-way ANOVA test for continuous variables.

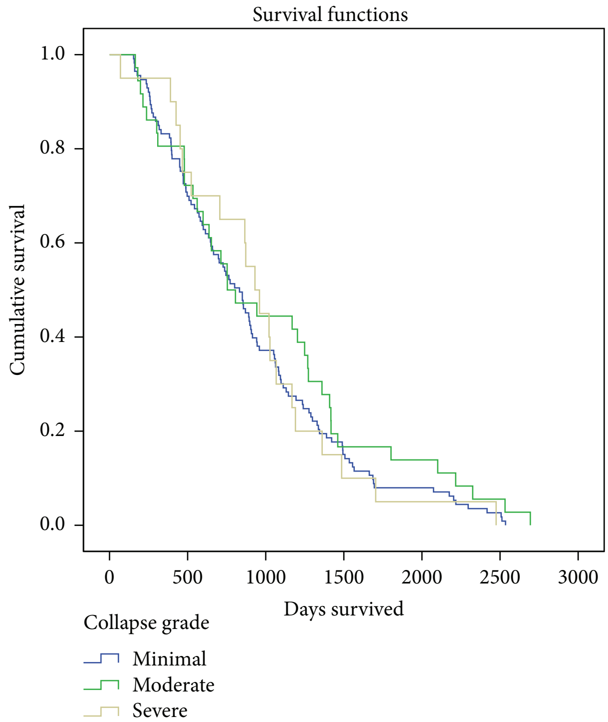

FIGURE 2: Kaplan-Meier survival plot of patients with different grades of fracture collapse up to 7.6 years after surgery; there was no statistically significant difference between patients with different group of collapse (log-rank test, $p = 0.503$).

status after operation were younger age ($p = 0.036$), higher MMSE marks ($p = 0.000$), higher MBI marks ($p = 0.010$), better premorbid walking status ($p = 0.000$), less severe fracture collapse ($p = 0.011$), and optimal lag screw position in centre-centre or centre-inferior position ($p = 0.020$) (see Table 4).

4. Discussion

In this study, it was demonstrated that fracture collapse was associated with poorer functional outcome, and this was independent of the patients' premorbid status. Moreover, complications occurred more commonly when patients had a more severe degree of collapse.

It is widely recognized in hip arthroplasty that shortening compromises the abductor muscle lever arm, resulting in weakness. In intracapsular neck of femur fractures, Zlowodzki et al. [12] studied 660 patients who have undergone screw fixation and concluded that a shortening of more than 10 mm resulted in significantly poorer short form 36 physical functioning scores compared to those with then 5 mm of shortening. Our study also suggests the same phenomenon to be true in geriatric intertrochanteric fractures, where increased fracture collapse indeed led to poorer walking function.

Our results showed that the independent risk factors for increased fracture collapse were old age, female sex, fracture comminution (31.A2 grading), increased operative time, poor fracture reduction quality, and suboptimal TAD. Of these factors, good fracture reduction appears to be of paramount importance. This is logical because doing so also effectively restores maximal contact of any available bony buttress [15, 21, 22]. For a dynamic device to work without excessive collapse, a majority of bone along the femur's circumference should remain intact and in contact. The well-known regions which provide effective bony support and load transfer between the main proximal and shaft fragments include the posterior medial calcar [23], the lateral wall [24], and the anteromedial region [25, 26]. As such, severe angulation, medialization of the proximal fragment [27], and lateral wall fractures [28, 29] result in a loss of bony support, and excessive fracture collapse.

Older female patients are more likely to have poor bone quality and reduced resistance to fracture collapse. A2 fractures are more comminuted and less stable than A1 fractures. As shown here, these patients were more likely to have eventual collapse. Fractures that required increased operative time also had increased likelihood of collapse. However, we are unable to conclude on whether it is prolonged operation itself or difficult fracture patterns which indirectly led to increased fracture collapse.

A number of studies have already pointed out the importance of implant position on outcomes. This was not consistency reproduced in our results possibly because of the low occurrences of poor TAD and poor implant positioning. Good implant positioning is known to be best determined by a small tip-apex distance of less than 25 mm and centre-centre or centre-inferior positioning of the lag screw in the femoral head in the AP and lateral radiographs [19, 22, 30, 31]. In all, surgeons must be meticulous with reduction and implant placement in trochanteric hip fractures while being mindful of risk factors such as osteoporosis and fracture comminution. The patients' functional outcome may be improved if precautions can be taken to limit the severity of fracture collapse.

There are a number of limitations to the study. Two slightly different implants were used in the group of patients, namely, as spiral blade and conventional lag screw. A standardized scoring system [32] was not used to grade functional outcomes because of the partially retrospective nature of data collection. We were not able to use an exact time point to define the patients' functional outcome as many of them suffered concomitant medical illness during or after rehabilitation and our study population had a highly variable timeline in recovery. We were unable to take pain into account in the clinical outcome analysis as we felt that there was poor documentation of this data in records. We were unable to find any verified grading system for the amount of collapse after DHS; nonetheless we felt that current method deemed simple enough and clinically applicable. The method through which we measured collapse of the metal implant may not always accurately reflect the true shortening between the bony fragments as an underestimation is likely in patients with implant migration in the femoral head.

The literature already contains many answered questions concerning improving patient survival and reducing complications. More research is needed to study how geriatric

Table 3: Ordinal regression of factors which predicted increasing severity of collapse. Value with a positive (+) estimate predicts more fracture collapse and that with a negative (−) estimate predicts less.

Estimated likelihood of increased fracture collapse in ordinal regression							
	Estimate	Standard error	Wald	df	Sig.	95% confidence interval	
Per day delay from admission to operation	−0.121	0.191	0.401	1.000	0.527	−0.496	0.254
Operative time per minute increase	0.021	0.008	6.484	1.000	**0.011**	**0.005**	**0.037**
Age at operation per year increase	0.049	0.023	4.369	1.000	**0.037**	**0.003**	**0.095**
MMSE per mark increase	0.025	0.023	1.182	1.000	0.277	−0.020	0.071
MBI per mark increase	0.007	0.008	0.701	1.000	0.402	−0.009	0.023
Poor premorbid walking status (independent versus assisted versus dependent)	−0.278	0.282	0.974	1.000	0.324	−0.831	0.274
Poor reduction quality (good versus acceptable versus poor)	1.112	0.240	21.510	1.000	**0.000**	**0.642**	**1.582**
Male versus female	−0.680	0.302	5.067	1.000	**0.024**	**−1.271**	**−0.088**
31.A1 class versus A2	−0.719	0.281	6.570	1.000	**0.010**	**−1.269**	**−0.169**
Screw versus blade	−0.156	0.284	0.301	1.000	0.583	−0.712	0.401
Operated by specialists (>6 years of experience)	0.360	0.311	1.338	1.000	0.247	−0.250	0.971
Suboptimal centre-centre or centre-inferior lag screw position	0.128	0.295	0.190	1.000	0.663	−0.449	0.706
ASA 1-2 versus 3-4	0.194	0.292	0.441	1.000	0.506	−0.378	0.765
Suboptimal tip-apex distance > 25 mm	1.978	1.011	3.829	1.000	**0.050**	**−0.003**	**3.959**
Pseudo R-square (Nagelkerke) = 0.244							

Table 4: Ordinal regression of factors which predicted better functional walking status after rehabilitation. Value with a positive (+) estimate predicts better walking status and that with a negative (−) estimate predicts a worse outcome.

Estimated likelihood of having better walking function in ordinal regression							
	Estimate	Standard error	Wald	df	Sig.	95% confidence interval	
Per day delay from admission to operation	0.069	0.194	0.126	1.000	0.722	−0.311	0.448
Operative time per minute increase	0.003	0.009	0.085	1.000	0.771	−0.014	0.020
Age at operation per year increase	−0.051	0.024	4.421	1.000	**0.036**	**−0.099**	**−0.003**
MMSE per mark increase	0.086	0.023	13.344	1.000	**0.000**	**0.040**	**0.132**
MBI per mark increase	0.021	0.008	6.587	1.000	**0.010**	**0.005**	**0.037**
Poor premorbid walking status (independent versus assisted versus dependent)	1.665	0.323	26.565	1.000	**0.000**	**1.032**	**2.297**
Poor reduction quality (good versus acceptable versus poor)	0.331	0.275	1.444	1.000	0.230	−0.209	0.871
Collapse grade (minimal versus moderate versus severe)	−0.650	0.256	6.445	1.000	**0.011**	**−1.151**	**−0.148**
Male versus female	−0.213	0.292	0.530	1.000	0.467	−0.786	0.360
31.A1 class versus A2	0.072	0.291	0.061	1.000	0.804	−0.498	0.642
Screw versus blade	−0.105	0.298	0.124	1.000	0.724	−0.690	0.480
Operated by specialists (>6 years of experience)	0.090	0.321	0.078	1.000	0.780	−0.540	0.719
ASA 1-2 versus 3-4	0.280	0.306	0.840	1.000	0.359	−0.319	0.880
No mechanical failure	0.787	0.684	1.326	1.000	0.250	−0.553	2.127
Not reoperated	1.779	1.046	2.890	1.000	0.089	−0.272	3.830
No lateral wall fracture	−0.476	0.526	0.820	1.000	0.365	−1.506	0.554
Suboptimal tip-apex distance > 25 mm*	22.688	0.000	—	1.000	—	22.688	22.688
Suboptimal centre-centre or centre-inferior lag screw position	−0.695	0.299	5.392	1.000	**0.020**	**−1.282**	**−0.108**
Pseudo R-square (Nagelkerke) = 0.504							

*Not enough valid cases to compute the significance of this item.

hip fracture patients can maintain better function. It is now evident that restoration and maintenance of the leg length is functionally important for both intracapsular [12, 13] and trochanteric hip fractures. Future implant design and improvements in treatment principles should take such findings into consideration.

5. Conclusion

Femoral shortening and collapse after DHS fixation are predisposed by old age, female sex, fracture comminution, poor reduction, and suboptimal implant placement. While the DHS is designed to allow for sliding and some degree of fracture collapse, those with severe collapse are more prone to eventual mechanical failure and complications. Increased collapse adversely affected patients' function in walking but did not appear to impair their survival.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] O. Olsson, L. Ceder, and A. Hauggaard, "Femoral shortening in intertrochanteric fractures—a comparison between the Medoff sliding plate and the compression hip screw," *Journal of Bone & Joint Surgery—British Volume*, vol. 83, no. 4, pp. 572–578, 2001.

[2] T. M. Barton, R. Gleeson, C. Topliss, R. Greenwood, W. J. Harries, and T. J. S. Chesser, "A comparison of the long gamma nail with the sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur: a prospective randomized trial," *The Journal of Bone and Joint Surgery—American Volume*, vol. 92, no. 4, pp. 792–798, 2010.

[3] M. J. Parker and H. H. G. Handoll, "Gamma and other cephalocondylic intramedullary nails versus extramedullary implants for extracapsular hip fractures in adults," *Cochrane Database of Systematic Reviews*, vol. 3, Article ID CD000093, 2008.

[4] M. B. Berkes, M. T. M. Little, L. E. Lazaro, R. M. Cymerman, D. L. Helfet, and D. G. Lorich, "Catastrophic failure after open reduction internal fixation of femoral neck fractures with a novel locking plate implant," *Journal of Orthopaedic Trauma*, vol. 26, no. 10, pp. e170–e176, 2012.

[5] K. Schneider, I. Zderic, B. Gueorguiev, R. G. Richards, and S. E. Nork, "What is the underlying mechanism for the failure mode observed in the proximal femoral locking compression plate? A biomechanical study," *Bone & Joint Journal Orthopaedic Proceedings Supplement B*, vol. 96, supplement 11, p. 130, 2014.

[6] J. Pajarinen, J. Lindahl, O. Michelsson, V. Savolainen, and E. Hirvensalo, "Pertrochanteric femoral fractures treated with a dynamic hip screw or a proximal femoral nail: a randomised study comparing post-operative rehabilitation," *The Journal of Bone & Joint Surgery—British Volume*, vol. 87, no. 1, pp. 76–81, 2005.

[7] R. Babst, N. Renner, M. Biedermann et al., "Clinical results using the Trochanter Stabilizing Plate (TSP): the modular extension of the Dynamic Hip Screw (DHS) for internal fixation of selected unstable intertrochanteric fractures," *Journal of Orthopaedic Trauma*, vol. 12, no. 6, pp. 392–399, 1998.

[8] J. L. Marsh, T. F. Slongo, J. Agel et al., "Fracture and dislocation classification compendium—2007: Orthopaedic Trauma Association Classification, Database and Outcomes Committee," *Journal of Orthopaedic Trauma*, vol. 21, no. 10, pp. S1–S6, 2007.

[9] H. Pervez, M. J. Parker, G. A. Pryor, L. Lutchman, and N. Chirodian, "Classification of trochanteric fracture of the proximal femur: a study of the reliability of current systems," *Injury*, vol. 33, no. 8, pp. 713–715, 2002.

[10] M. J. Parker, R. J. K. Khan, J. Crawford, and G. A. Pryor, "Hemiarthroplasty versus internal fixation for displaced intracapsular hip fractures in the elderly: a randomised trial of 455 patients M," *The Journal of Bone & Joint Surgery—British Volume*, vol. 84, no. 8, pp. 1150–1155, 2002.

[11] M. Zlowodzki, A. Jönsson, R. Paulke, P. J. Kregor, and M. Bhandari, "Shortening after femoral neck fracture fixation: is there a solution?" *Clinical Orthopaedics and Related Research*, vol. 461, pp. 213–218, 2007.

[12] M. Zlowodzki, O. Brink, J. Switzer et al., "The effect of shortening and varus collapse of the femoral neck on function after fixation of intracapsular fracture of the hip: a multi-centre cohort study," *The Journal of Bone & Joint Surgery—British Volume*, vol. 90, no. 11, pp. 1487–1494, 2008.

[13] Y. A. Weil, A. Khoury, I. Zuaiter, O. Safran, M. Liebergall, and R. Mosheiff, "Femoral neck shortening and varus collapse after navigated fixation of intracapsular femoral neck fractures," *Journal of Orthopaedic Trauma*, vol. 26, no. 1, pp. 19–23, 2012.

[14] P. Platzer, G. Thalhammer, G. E. Wozasek, and V. Vécsei, "Femoral shortening after surgical treatment of trochanteric fractures in nongeriatric patients," *Journal of Trauma—Injury, Infection and Critical Care*, vol. 64, no. 4, pp. 982–989, 2008.

[15] C. Fang, T. W. Lau, T. M. Wong, H. L. Lee, and F. Leung, "Sliding hip screw versus sliding helical blade for intertrochanteric fractures: a propensity score-matched case control study," *The Bone & Joint Journal*, vol. 97, no. 3, pp. 398–404, 2015.

[16] T. Lau, C. Fang, and F. Leung, "The effectiveness of a geriatric hip fracture clinical pathway in reducing hospital and rehabilitation length of stay and improving short-term mortality rates," *Geriatric Orthopaedic Surgery & Rehabilitation*, vol. 4, no. 1, pp. 3–9, 2013.

[17] M. F. Folstein, S. E. Folstein, and P. R. McHugh, "'Mini-mental state'. A practical method for grading the cognitive state of patients for the clinician," *Journal of Psychiatric Research*, vol. 12, no. 3, pp. 189–198, 1975.

[18] S. Shah, F. Vanclay, and B. Cooper, "Improving the sensitivity of the Barthel Index for stroke rehabilitation," *Journal of Clinical Epidemiology*, vol. 42, no. 8, pp. 703–709, 1989.

[19] M. R. Baumgaertner, S. L. Curtin, D. M. Lindskog, and J. M. Keggi, "The value of the tip-apex distance in predicting failure of fixation of peritrochanteric fractures of the hip," *The Journal of Bone & Joint Surgery—American Volume*, vol. 77, no. 7, pp. 1058–1064, 1995.

[20] M. R. Baumgaertner, S. L. Curtin, and D. M. Lindskog, "Intramedullary versus extramedullary fixation for the treatment of intertrochanteric hip fractures," *Clinical Orthopaedics and Related Research*, no. 348, pp. 87–94, 1998.

[21] J. Ito, Y. Takakubo, K. Sasaki, J. Sasaki, K. Owashi, and M. Takagi, "Prevention of excessive postoperative sliding of the short femoral nail in femoral trochanteric fractures," *Archives of Orthopaedic and Trauma Surgery*, vol. 135, no. 5, pp. 651–657, 2015.

[22] K.-K. Hsueh, C.-K. Fang, C.-M. Chen, Y.-P. Su, H.-F. Wu, and F.-Y. Chiu, "Risk factors in cutout of sliding hip screw in intertrochanteric fractures: an evaluation of 937 patients," *International Orthopaedics*, vol. 34, no. 8, pp. 1273–1276, 2010.

[23] T. M. Barton, R. Gleeson, C. Topliss, R. Greenwood, W. J. Harries, and T. J. S. Chesser, "A comparison of the long gamma nail with the sliding hip screw for the treatment of AO/OTA 31-A2 fractures of the proximal part of the femur: a prospective randomized trial," *The Journal of Bone & Joint Surgery—American Volume*, vol. 92, no. 4, pp. 792–798, 2010.

[24] C.-E. Hsu, C.-M. Shih, C.-C. Wang, and K.-C. Huang, "Lateral femoral wall thickness. A reliable predictor of post-operative lateral wall fracture in intertrochanteric fractures," *The Bone & Joint Journal*, vol. 95, no. 8, pp. 1134–1138, 2013.

[25] S. Chang, Y. Zhang, Z. Ma, Q. Li, J. Dargel, and P. Eysel, "Fracture reduction with positive medial cortical support: a key element in stability reconstruction for the unstable pertrochanteric hip fractures," *Archives of Orthopaedic and Trauma Surgery*, vol. 135, no. 6, pp. 811–818, 2015.

[26] C.-G. Kim, S.-H. Kweon, H.-J. Han, and J.-S. Hwang, "The antero-medial cortex overlapped reduction of unstable intertrochanteric fractures," *Hip & Pelvis*, vol. 25, no. 4, pp. 280–285, 2013.

[27] M. J. Parker, "Trochanteric hip fractures. Fixation failure commoner with femoral medialization, a comparison of 101 cases," *Acta Orthopaedica Scandinavica*, vol. 67, no. 4, pp. 329–332, 1996.

[28] Y. Gotfried, "The lateral trochanteric wall: a key element in the reconstruction of unstable pertrochanteric hip fractures," *Clinical Orthopaedics and Related Research*, vol. 425, pp. 82–86, 2004.

[29] H. Palm, S. Jacobsen, S. Sonne-Holm, and P. Gebuhr, "Integrity of the lateral femoral wall in intertrochanteric hip fractures: an important predictor of a reoperation," *The Journal of Bone & Joint Surgery—American Volume*, vol. 89, no. 3, pp. 470–475, 2007.

[30] K. De Bruijn, D. den Hartog, W. Tuinebreijer, and G. Roukema, "Reliability of predictors for screw cutout in intertrochanteric hip fractures," *The Journal of Bone & Joint Surgery—American Volume*, vol. 94, no. 14, pp. 1266–1272, 2012.

[31] H. Andruszkow, M. Frink, C. Frömke et al., "Tip apex distance, hip screw placement, and neck shaft angle as potential risk factors for cut-out failure of hip screws after surgical treatment of intertrochanteric fractures," *International Orthopaedics*, vol. 36, no. 11, pp. 2347–2354, 2012.

[32] E. Nordin, E. Rosendahl, and L. Lundin-Olsson, "Timed 'Up & Go' test: reliability in older people dependent in activities of daily living—focus on cognitive state," *Physical Therapy*, vol. 86, no. 5, pp. 646–655, 2006.

Hindawi Publishing Corporation
BioMed Research International
Volume 2016, Article ID 6047876, 5 pages
http://dx.doi.org/10.1155/2016/6047876

Research Article

The Role of a Primary Arthroplasty in the Treatment of Proximal Tibia Fractures in Orthogeriatric Patients

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Received 21 October 2015; Accepted 7 December 2015

Academic Editor: Hitendra K. Doshi

The total knee arthroplasty (TKA) is the gold standard for patients with an advanced symptomatic gonarthrosis. However, there are very few publications dealing with the primary TKA for patients with a proximal tibia fracture. In our retrospective study we evaluated 30 patients treated with a TKA for a proximal tibia fracture in our institution between 01/2008 and 12/2014. We collected the following statistical data from each patient: age, classification of the fracture (AO-classification), type of prosthesis used, length of the operation and hospitalization, and complications during the follow-up. We used the Knee Society Score (KSS) and the WOMAC score to evaluate the function. The Knee Society Score showed an average "general knee score" (KSS1) of 81.1 points and an average "functional knee score" (KSS2) of 74.5 points. The average WOMAC score was 78.6 points. Immediate postoperative mobilization with the possibility of a full-weight bearing is of crucial importance for the geriatric patients to maintain the mobility they had prior to the operation and reduce medical complications. Because of these advantages, the primary TKA seems to be a promising alternative to the ORIF of a proximal tibia fracture in the orthogeriatric patient.

1. Introduction

The total knee arthroplasty is the gold standard for patients with an advanced, symptomatic gonarthrosis. It is a well-established therapy based on numerous studies [1–3]. In contrast there are not many publications dealing with the primary arthroplasty for complex tibia plateau fractures. In the current literature there are only a few studies, each with a very small patient population of less than 15, dealing with this subject (Table 1). However the TKA for a proximal tibia fracture seems to be a promising alternative, especially for the increasing number of orthogeriatric patients. Although the proximal tibia fracture is rare in that it comprises only 1% of all fractures [4], the incidence in the elderly population is increasing [5, 6]. In contrast to a younger patient, for the orthogeriatric patient the underlying cause is mostly a low energy trauma. Due to the often preexisting osteoporosis that is present in that population, we see a lot more complex fractures with a big defect of the articular surface [7]. Because of those defects, most of the patients who undergo an open reduction and internal fixation (ORIF) will only be allowed a partial weight bearing postoperatively. But for the elderly patient the immediate postoperative mobilization with full-weight bearing is crucial to maintain the mobility they had prior to the operation. It is a known fact that if, due to reduced proprioceptive sensibilities or to preexisting comorbidities, a partial weight bearing cannot be achieved, the risk of thrombosis, pulmonary embolism, and pneumonia, as well as the reduction of muscular mass (and proprioceptive abilities), increases postoperatively. Those factors can lead to a complete loss of mobility and also to an increase rate of the overall mortality.

2. Methods

In this retrospective study we collected the data of 30 patients which were treated with a TKA for a proximal tibia fracture between 01/2008 and 12/2014 in our institution. This patient group was evaluated using the Knee Society Score (KSS) rating system [8] and the WOMAC score [9]. The mean follow-up was 27 months (12–48 months) with a minimum follow-up of 12 months. Overall we were able to collect the data from 73% of all patients treated with a TKA for a proximal tibia fracture in this period. 13 patients were

Table 1: Publications dealing with primary TKA according to D. Pape [4].

Publication	Year	Patients (n)
Kilian [10]	2003	2
Nau et al. [11]	2003	3
Nourissat et al. [12]	2006	4
Schwarz et al. [13]	2008	10
Vermeire and Scheerlinck [23].	2010	12
Malviya et al. [7]	2011	15
n		46

Table 2: AO-classification of fractures und prostheses used.

	B1	B2	B3	C1	C2	C3
Hinged prosthesis $n = 24$	0	2	4	5	5	8
e.motion $n = 6$	1	4	1	0	0	0

examined in our hospital during an outpatient visit. 9 patients could only be reached via telephone due to various reasons. This latter group of patients was included in the study despite the absence of a clinical examination. The WOMAC score and the functional part of the KSS can be obtained without a physical examination of the patient. For the patients we could not examine during the follow-up, their range of motion was obtained with the help of their physiotherapist or their physician at home. Concerning the stability (anteroposterior and mediolateral) all the patients surveyed by phone had coupled/hinged prostheses models, so a normal stability was assumed. In addition to the scores we collected some statistical data of each patient: the age at the time of surgery, the AO-classification of the fracture, the comorbidities, the type of prosthesis, the average length of the operation and hospitalization, and the postoperative complications were recorded.

3. Results

The mean age of the patient at the time of surgery was 78.4 (59–93) years. We treated 17 female and 13 male patients. The fractures were classified according to the AO-classification. We had a total of 0 type A-fractures, 13 type B-fractures (Figure 2), and 17 type C-fractures (Figure 3) (6x AO 41B2, 5x AO 41B3, 5x AO 41C1, 7x AO 41C2, and 7x 41C3) (Table 2). The NextGen/Rotating Hinge prosthesis (Zimmer) was 13x (1x41B2, 2x41B3, 2x41C1, 3x41C2, and 5x41C3), the Innex SC prosthesis (Zimmer) was 11x (1x41B2, 2x41B3, 3x41C1, 2x41C2, and 3x41C3), and e.motion knee prosthesis (Braun) was 6x (1x41B1, 4x41B2, and 1x41B3) implanted (Table 2). In our institution the operations were only performed by two surgeons. The average length of the operation was 119 (72–150) minutes and the average length of hospitalization was 26.7 (15–35) days. $n = 24$ patients were released in a rehabilitation, $n = 2$ patients were released to a rest home, $n = 1$ patient was released to his home, and $n = 1$ patient was released in a psychiatry. $n = 2$ patients died during hospitalization, and $n = 1$ patient died 3 years later. Overall we saw 7 patients with a complication that required a further surgical treatment (wound healing deficit: 3, intraoperative periprosthetic fracture: 1, infection of the TKA: 1, residual intraarticular cement: 1, and loosening of the prosthesis component: 1). We did not see any nonsurgical complications such as a thrombosis or a pulmonary embolism. Two patients died due to complications related to a necessary further surgical treatment because of a complication of the TKA (1 prosthetic infection and 1 periprosthetic fracture) and one patient died three years after the operation due to natural causes.

Table 3: Summary of all outcome measures 01/2008–12/2014 ($n = 22$).

	Score (max)	Mean score (range)
Knee Society Score	KSS1 (100)	81.1 (54–94)
	KSS2 (100)	74.5 (−20–100)
WOMAC score	WOMAC (100)	78.6 (36.7–96.2)

Table 4: Results of the Knee Society Score 01/2008–12/2014 ($n = 22$).

Knee Society Score	Excellent	Good	Fair	Poor
KSS1	14	2	1	5
KSS2	13	3	1	5

Table 5: Summary of all outcome measures 01/2013–12/2014 ($n = 9$).

	Score (max)	Mean score (range)
Knee Society Score	KSS1 (100)	87.2 (69–94)
	KSS2 (100)	77.2 (−20–100)
WOMAC score	WOMAC (100)	83.2 (36.7–96.2)

Table 6: Results of the Knee Society Score 01/2013–12/2014 ($n = 9$).

Knee Society Score	Excellent	Good	Fair	Poor
KSS1	8	0	1	0
KSS2	8	0	0	1

The American Knee Society Clinical Rating Score (KSS) is composed of two components, a "knee score" (KSS1) and a "functional score" (KSS2) (80–100 points = excellent, 70–79 = good, 60–69 = fair, and below 60 = poor). In our study the patients achieved KSS1 of ø 81.1 points (94–54 points), a KSS2 of ø 74.5 (100 to −20 points), and a WOMAC score of ø 78.6 points (96.2 to 36.7 points) (Tables 3 and 4). Over the last few years we saw an improvement in the clinical outcome in our institution so we decided to set up a subgroup population who had been treated with a TKA for a proximal tibia fracture between 01/2013 and 12/2014. In the subgroup population we saw better functional results compared to the overall population group (Figure 1). These patients achieved a KSS1 of ø 87.2 points (94–69 points), a KSS2 of ø 77.2 points (100 to −20 points), and the WOMAC score of ø 83.2 points (36.7 and 97.7 points) (Tables 5 and 6).

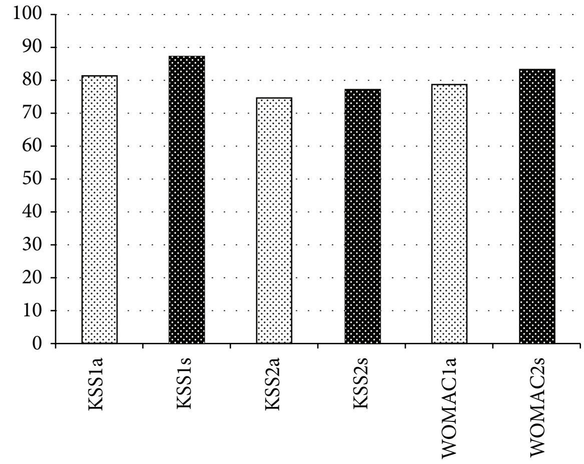

Figure 1: Results of all patients (a) $n = 22$ (01/2008–12/2014) versus subgroup(s) $n = 9$ (01/2013–12/2014).

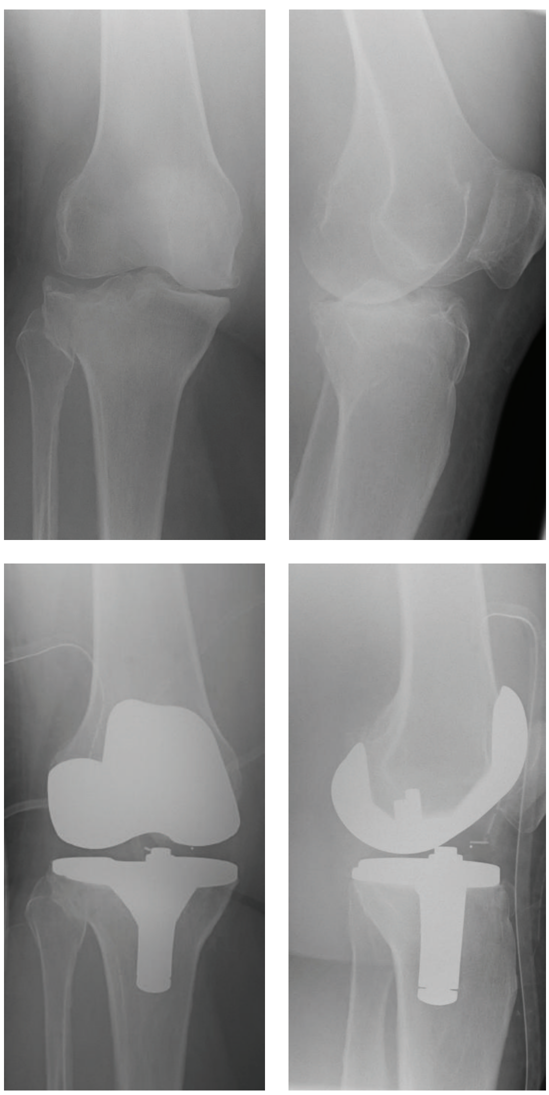

Figure 2: Female, age 83, tibia fracture AO 41B3, e.motion (Braun), postoperative X-ray, KSS1 83, KSS2 80, and WOMAC 87 (12th month's follow-up).

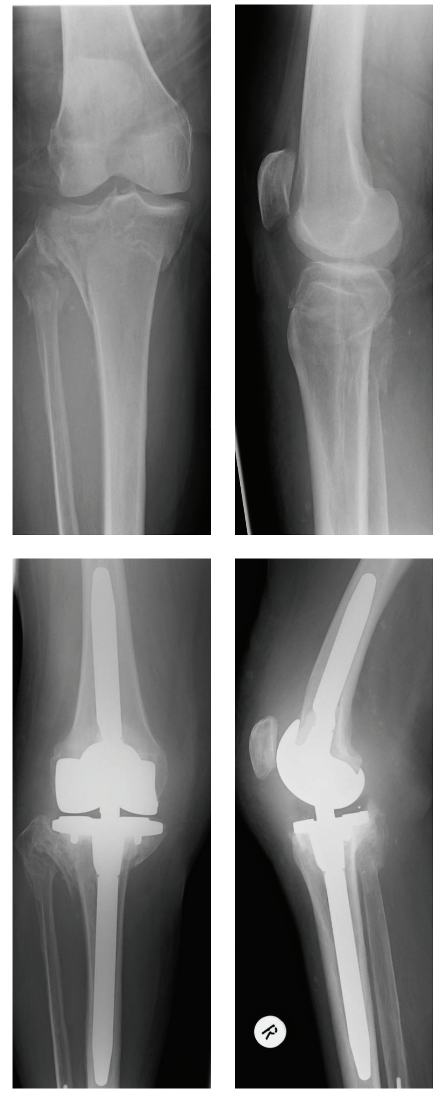

Figure 3: Female, age 86, tibia fracture AO 41C3, Innex SC (Zimmer), postoperative X-ray, KSS1 90, KSS2, and WOMAC 85 (13th month's follow-up).

4. Discussion

According to the current literature there is very limited experience with a TKA for a proximal tibia fracture. The results of our study are comparable to the good clinical results seen after a TKA shown in the literature [10–13].

There is a steady increase in the incidence of a tibia plateau fracture in the elderly over the past years [5, 6]. 95% of the patients over the age of 70 with a proximal tibia fracture have a concomitant osteoporosis [14]. Therefore in this population group we see a higher incidence of tibia plateau fracture with a significant defect of the articular surface compared to a younger population group [15]. These factors contribute to more complicated ORIFs in these patients and the literature shows poorer long-term results after ORIF in those group of patients [6, 10, 16, 17]. In cases where ORIF of an intraarticular fracture of the knee joint was preformed, there was a threefold increase in the number of cases with a reported osteoarthritis or necrosis of the tibial and femoral condyles [6]. Any secondary TKA due to a failed ORIF of a tibia plateau fracture shows poorer long-term results with an increased complication rate compared to a primary TKA [2, 10, 16, 18, 19]. Also a higher rate of secondary loss of reposition is described for the ORIF of orthogeriatric patients [6, 10, 12, 16, 20]. One of the main reasons for that is the poor bone stock in those patients due the preexisting osteoporosis. To achieve a sufficient stability for a complex proximal tibia fracture by a conventional plate osteosynthesis ORIF is often difficult [21, 22] and in most cases the osteosynthesis allows only a partial weight bearing for the first few weeks postoperatively. In our hospital we have a specialized unit for geriatric trauma patients. Our main goal is treating the joint fracture with single operation which allows a full-weight bearing postoperatively to allow early mobilization of the patient. In addition to the "surgical related" problems in this group of patients, there are age related "biological" problems which must be taken into consideration as well. Due to a sarcopenia, a preexisting limitation of mobility, cognitive impairment/dementia, or delirium, a partial weight bearing is impossible for patients in this group [4]. With the ability of a full-weight bearing postoperatively the mobilization of those patients is much easier which, in turn, may reduce the risks of medical complications [7]. In addition, the proprioceptive sensibilities and the muscle mass can be retained. The primary TKA for the treatment of a proximal tibia fracture in the elderly is a challenging operation. Over the last few years we saw better results in the clinical outcome, which we explained as being due to an improvement of the regimen within our institution, as well as an improvement in technical skills. In 80% of those fractures we used a hinged prosthesis for the TKA (NextGen (Zimmer) or Innex SC (Zimmer)). The hinged components of the prosthesis allow a high degree of stabilization for an often preexisting ligamentous instability. The longer stem components allow a better fixation in the osteoporotic bone. Those advantages mentioned above outweigh the limited options available for a revision of the prostheses if necessary. In our opinion the primary TKA for the treatment of proximal tibia fractures in the orthogeriatric patient require a very strict and individualized indication. In our study the average age was 78.4 years. Besides the age of the patient, when deciding whether to utilize a TKA there are other factors which should be taken into consideration such as the mobility prior to the injury, cognitive function, the fracture classification, the bone stock, the ligamentous stability, and the muscle mass of the patient.

5. Conclusion

Because of the benefits shown above for the geriatric patients, especially the immediate postoperative mobilization with full-weight bearing, associated risks like thrombosis, pulmonary embolism, and pneumonia could be reduced. Additionally the loss of the proprioceptive sensibilities and the loss of muscle mass can be minimized. And these factors, in turn, may reduce the risk of the overall mortality rate and loss of mobility in those patients. Regarding the existing literature and the good results in our study the concept of the primary total knee arthroplasty (TKA) for tibia plateau fractures in orthogeriatric patients seems to be an interesting alternative to the osteosynthetic treatment (ORIF).

We do not see this as a paradigm shift but instead as a good alternative for a certain patient group that requires a strict indication and an experienced surgeon.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

References

[1] R. Lohmann, K. Haid, U. Stöckle, and M. Raschke, "Epidemiologie und perspektiven der alterstraumatologie," *Der Unfallchirurg*, vol. 110, no. 6, pp. 553–562, 2007.

[2] K. J. Saleh, P. Sherman, P. Katkin et al., "Total knee arthroplasty after open reduction and internal fixation of fractures of the tibial plateau," *The Journal of Bone and Joint Surgery*, vol. 83, no. 8, pp. 1144–1148, 2001.

[3] T. Vogel, P. Kampmann, D. Bürklein et al., "Versorgungswirklichkeit bei osteoporosebedingten Frakturen in der deutschen Unfallchirurgie. Ein Beitrag zur Versorgungsforschung," *Unfallchirurg*, vol. 111, no. 2, pp. 869–877, 2008.

[4] D. Pape, A. Hoffmann, T. Gerich, M. Van der Kerkhofe, M. Weber, and H. Pape, "Frakturen des Kniegelenks im hohen Lebensalter," *Der Orthopäde*, vol. 43, no. 4, pp. 365–373, 2014.

[5] U. Bengnér, O. Johnell, and I. Redlund-Johnell, "Increasing incidence of tibia condyle and patella fractures," *Acta Orthopaedica*, vol. 57, no. 4, pp. 334–336, 1986.

[6] T. Gerlich, M. Blauth, F. Witte, P. Lobenhoffer, and C. Krettek, "Kniegelenksendoprothetik nach Tibiakopffrakturen im höheren Alter," *Der Unfallchirurg*, vol. 104, no. 3, pp. 50–56, 2001.

[7] A. Malviya, M. R. Reed, and P. F. Partington, "Acute primary total knee arthroplasty for peri-articular knee fractures in patients over 65 years of age," *Injury*, vol. 42, no. 11, pp. 1368–1371, 2011.

[8] J. N. Insall, L. D. Dorr, R. D. Scott, and W. N. Scott, "Rationale of The Knee Society clinical rating system," *Clinical Orthopaedics and Related Research*, no. 248, pp. 13–14, 1989.

[9] N. Bellamy, J. Campbell, J. Stevens, L. Pilch, C. Stewart, and Z. Mahmood, "Validation study of a computerized version of the Western Ontario and McMaster Universities VA3.0 Osteoarthritis Index," *Journal of Rheumatology*, vol. 24, no. 12, pp. 2413–2415, 1997.

[10] U. Kilian, "Kniegelenksendoprothese zur primären Therapie von intraartikulären Tibiakopffrakturen im höheren Alter," *Der Unfallchirurg*, vol. 106, pp. 1046–1050, 2003.

[11] T. Nau, E. Pflegerl, J. Erhardt, and V. Vecsei, "Primary knee arthroplasty for periarticular fractures," *The Journal of Arthroplasty*, vol. 18, no. 2, pp. 968–971, 2003.

[12] G. Nourissat, E. Hoffmann, C. Hémon, L. Rillardon, P. Guigui, and A. Sautet, "Arthroplastie totale de genou pour fracture récente grave de l'épiphyse tibiale proximale chez le sujet âgé," *Revue de Chirurgie Orthopédique et Traumatologique*, vol. 92, no. 3, pp. 242–247, 2006.

[13] N. Schwarz, W. Buchinger, M. Mähring et al., "Knieprothese als Ersttherapie bei proximaler Tibiafraktur," *Unfallchirurg*, vol. 111, no. 2, pp. 928–932, 2008.

[14] E. R. Bogoch, V. Elliot-Gibson, D. E. Beaton, S. A. Jamal, R. G. Josse, and T. M. Murray, "Effective initiation of osteoporosis diagnosis and treatment for patients with a fragility fracture in an orthopaedic environment," *Journal of Bone and Joint Surgery*, vol. 88, no. 1, pp. 25–34, 2006.

[15] W. Petersen, T. Zantop, and M. Raschke, "Fracture of the tibial head," *Der Unfallchirurg*, vol. 109, no. 3, pp. 219–232, 2006.

[16] T. Gerlich, U. Bosch, E. Schmidt, P. Lobenhoffer, and C. Krettek, "Kniegelenkendoprothetik nach tibiakopffrakturen mittelfristige ergebnisse einer kohortenanalyse," *Der Unfallchirurg*, vol. 104, no. 5, pp. 414–419, 2001.

[17] A. M. Ali, M. El-Shafie, and K. M. Willett, "Failure of fixation of tibial plateau fractures," *Journal of Orthopaedic Trauma*, vol. 16, no. 5, pp. 323–329, 2002.

[18] E. C. Papadopoulos, J. Parvizi, C. H. Lai, and D. G. Lewallen, "Total knee arthroplasty following prior distal femoral fracture," *Knee*, vol. 9, no. 4, pp. 267–274, 2002.

[19] N. G. Weiss, J. Parvizi, R. T. Trousdale, R. D. Bryce, and D. G. Lewallen, "Total knee arthroplasty in patients with a prior fracture of the tibial plateau," *Journal of Bone & Joint Surgery*, vol. 85, no. 2, pp. 218–221, 2003.

[20] S. E. Honkonen, "Indications for surgical treatment of tibial condyle fractures," *Clinical Orthopaedics and Related Research*, no. 302, pp. 199–205, 1994.

[21] P. Hertel, "Tibiakopffrakturen," *Der Unfallchirurg*, vol. 100, no. 3, pp. 508–523, 1997.

[22] G. Peicha, W. Grechenig, F. J. Seibert, and J. Passler, "Frühsekundäre Kniegelenksendoprothese nach Tibiakopftrümmerfrakturen," *European Journal of Trauma*, vol. 1, no. 3, pp. 36–39, 2001.

[23] J. Vermeire and T. Scheerlinck, "Early primary total knee replacement for complex proximal tibia fractures in elderly and osteoarthritic patients," *Acta Orthopaedica Belgica*, vol. 76, no. 6, pp. 785–793, 2010.

Hindawi Publishing Corporation
BioMed Research International
Volume 2016, Article ID 8431213, 6 pages
http://dx.doi.org/10.1155/2016/8431213

Research Article

One-Year Outcome of Geriatric Hip-Fracture Patients following Prolonged ICU Treatment

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Received 12 October 2015; Revised 5 December 2015; Accepted 13 December 2015

Academic Editor: Hitendra K. Doshi

Purpose. Incidence of geriatric fractures is increasing. Knowledge of outcome data for hip-fracture patients undergoing intensive-care unit (ICU) treatment, including invasive ventilatory management (IVM) and hemodiafiltration (CVVHDF), is sparse. *Methods*. Single-center prospective observational study including 402 geriatric hip-fracture patients. Age, gender, the American Society of Anesthesiologists (ASA) classification, and the Barthel index (BI) were documented. Underlying reasons for prolonged ICU stay were registered, as well as assessed procedures like IVM and CVVHDF. Outcome parameters were in-hospital, 6-month, and 1-year mortality and need for nursing care. *Results*. 15% were treated > 3 days and 68% < 3 days in ICU. Both cohorts had similar ASA, BI, and age. In-hospital, 6-month, and 12-month mortality of ICU > 3d cohort were significantly increased ($p = 0.001$). Most frequent indications were cardiocirculatory pathology followed by respiratory failure, renal impairment, and infection. 18% of patients needed CVVHDF and 41% IVM. In these cohorts, 6-month mortality ranged > 80% and 12-month mortality > 90%. 100% needed nursing care after 6 and 12 months. *Conclusions*. ICU treatment > 3 days showed considerable difference in mortality and nursing care needed after 6 and 12 months. Particularly, patients requiring CVVHDF or IVM had disastrous long-term results. Our study may add one further element in complex decision making serving this vulnerable patient cohort.

1. Introduction

By 2030, 25% of the western European population is expected to be at least 65 years of age [1]; by 2050, the elderly population will almost triple [2].

Until the age of 85, 11% of women and 5% of men are hospitalized because of femoral fractures [3, 4]. Long-term mortality in this cohort, compared with people of the same age without fracture, is 1.15 : 1, a 20% increase [5]. Thus, successful treatment of these fractures is becoming increasingly important. Over the last years, several models of shared orthogeriatric care have been developed worldwide to improve patients' outcomes. As part of these models, a perioperative observational period was developed as a standard procedure for this patient sample. Monitoring in the postoperative period is also part of current guidelines [6, 7]. Triage studies have demonstrated that patients admitted to ICUs have improved survival compared to rejected patients [8–10]. Elderly patients may have worse prognoses because of more comorbid conditions and fewer physiologic reserves. Some authors recently documented age as an independent risk factor for mortality [11, 12] but not always a factor in predicting worse outcome [13]. Today, plenty of data concerning comorbidities and chronic health conditions identified as risk factors, especially for hip-fracture patients' outcomes, are available. They are associated with poor outcomes (i.e., prolonged hospitalization, higher complication rate, poorer functional levels, and increased mortality) [14, 15]. With the current aging population, more complex procedures, and increasing expectations, demand for ICUs will increase further. Particularly, pulmonary complications and renal failure due to a preexisting chronic failure are severe and life-limiting complications. It is reported that incidence of hospitalization secondary to community-acquired pneumonia doubles in patients aged > 60 years [16]. Posthospitalization outcome data following ICU-dependent complications in geriatric trauma patients are sparsely available. In particular, outcome data after invasive ventilation and filtration due to acute renal failure do not exist for this kind of cohort. Furthermore, short-term survival is probably not the most important factor considered when making treatment decisions in this cohort; we suggest that invasive ICU procedures may increase the likelihood of less favorable post-ICU outcomes such as persistent need of nursing care.

Accordingly, dependent on reasons and assessed procedures for an ICU treatment extending past the normal postoperative period of 1 to 3 days, we aimed to detect considerable differences in 6- and 12-month mortality as well as persistent need of nursing care of these patients.

2. Patients and Methods

Patients at least 60 years old with proximal femoral fractures (ICD 10 S 72.0–72.2) were included in this prospective single-center observational study. Research nurses and/or senior physicians collected data.

Criteria for exclusion were multiple traumas (ISS $\geq$ 16) and malignoma-associated fractures. All patients were surgically treated with either internal fixation or hip arthroplasty. The inclusion period was from April 1, 2009, to September 30, 2011. We obtained the approval of the Ethics Committee of the University of Marburg (AZ 175/08). All of the patients or their legal representatives gave their written consent.

We documented patient age, gender, the American Society of Anesthesiologists (ASA) classification, and fracture type. Patients were requested to give information about their prefracture functional status. We measured the functional status by the Barthel index (BI, Hamburg Classification Manual). We registered the prevalence of ICU stay, underlying reasons for admission, and length of stay in the ICU during the hospitalization period and assessed procedures like invasive ventilator management (IVM) and renal failure demanding CVVHDF. According to further evaluation, we subdivided our patients into 3 groups: those who were not treated in the ICU (nICU, i.e., no intensive-care unit), those who stayed 1 to 3 days in the ICU (sICU, i.e., short intensive-care unit), and those who stayed > 3 days (pICU, i.e., prolonged intensive-care unit). We defined outcome parameters as in-hospital mortality, 6-month mortality and nursing dependency, and 1-year mortality and nursing dependency.

We collected data in a FileMaker database (FileMaker, Inc. 5201 Patrick Henry Drive Santa Clara, CA 95054, USA). We performed double entry with a plausibility check to improve data quality. We used Predictive Analysis Software (PASW) version 22.0 (SPSS Inc., Chicago, IL, USA) for descriptive statistics and explorative data analysis, with the results being presented as numbers and percentages or as means, standard deviations, and 95% confidence intervals. We tested numerous data using the Wilcoxon test or the t-test, depending on the Kolmogorov-Smirnov test for normal distribution. We tested all dichotomies using Fisher's exact test. The outcome parameters in hospital mortality, 6-month mortality, and 12-month mortality were analyzed additionally by multivariate analysis addressing the covariates age, gender, BI, ASA, Charlson index, BMI, time until operation, and ICU cohort. For all tests, we assumed statistical significance at $p \leq 0.05$.

3. Results

In the observational period, we were able to include 402 patients. The baseline characteristics of all patients are illustrated in Table 1. Patients underwent operative treatment for hip-related fracture (intramedullary nail/hemiarthroplasty) in the first 24 h. The pICU cohort was operated with a slight delay compared to the sICU cohort (17.2 ± 0.8 h versus 23.3 ± 2.3 h, $p = 0.041$).

We observed 336 (85%) of all patients in the ICU postoperatively for a mean of 2.5 (±3.7) days. The pICU group included 61 patients. None of the patients who were admitted directly to the standard-care unit required ICU admission in the course of inpatient care.

Patients with ICU stays were significantly older than those in group nICU (79 ± 8 versus 82 ± 9, $p = 0.008$). The ICU cohorts showed significantly more female patients and significantly higher ASA scores ($p \leq 0.001$). Comparing the pICU cohort to the sICU cohort, the differences concerning the abovementioned characteristics seem to be sparse. Both groups had similar ASA, BI, and age. Nevertheless, the pICU cohort showed a significantly higher amount of prefracture nursing care needed, including 144 (52%) in need of care versus 44 (72%) patients in the sICU cohort ($p = 0.042$). CCI was also increased significantly in the pICU cohort ($p \leq 0.001$).

Comparing the data of further clinical courses, the in-hospital mortality of the pICU cohort was significantly increased (3% versus 26%). The 6- and 12-month mortality were equally increased and statistically significantly compared to the cohort of nICU patients and sICU patients as well (18% versus 48% and 26% versus 59%). The 6-month and 12-month nursing-care need showed equal tendency (67% versus 85% and 66% versus 84%) without reaching a statistically significantly higher amount in the pICU cohort ($p = 0.072$ versus $p = 0.123$; Table 2).

A multivariate analysis for the mortality endpoints "in-hospital mortality," "6-month mortality," and "12-month mortality," including the variables age, gender, BI, ASA, Charlson index, BMI, time until operation, and ICU cohort, was performed. As expected, the ASA and ICU cohorts were independent risk factors affecting the different mortality endpoints. The Charlson index became significant in the 6- and 12-month mortality analysis (Table 3).

As mentioned above, 61 patients were treated for more than 3 days in our ICU. Regarding the underlying reasons concerning a prolonged ICU treatment period, we noticed the main treatment diagnosis during stay: the largest group of 17 patients suffered from cardiac pathology subdivided into arrhythmia, ischemia, or failure. Two patients in this subgroup underwent cardiopulmonary resuscitation (CPR), 1 following ventricular fibrillation and 1 further following myocardial failure with cardiac arrest. The second largest group included primary respiratory failure ($N = 10$), renal

Table 1: Baseline data, given as mean and standard deviation (±) or as odds ratio with confidence interval (CI). For all tests, statistical significance was assumed at $p \leq 0.05$.

	Given	nICU	sICU	pICU	p = sICU/pICU
Number of patients	$N = 402$	66	275	61	—
Patients' age	Mean (SD)	79 (±8)	82 (±8)	82 (±9)	*0.970*
	95% CI	77–81	81–83	80–84	—
Gender	Male (%)	14 (21%)	71 (26%)	24 (39%)	—
	Female (%)	52 (79%)	204 (74%)	37 (61%)	*0.049*
BMI	Mean (SD)	16 (±33)	18 (±29)	19 (±28)	*0.999*
ASA score	Mean (SD)	2.7 (±0.7)	2.9 (±0.6)	3.1 (±0.6)	*0.107*
Prefracture Barthel index	95% CI	2.5–2.8	2.9–3.0	2.9–3.2	—
	Mean (SD)	89 (±21)	79 (±24)	72 (±28)	*0.300*
Prefracture nursing-care need	95% CI	83–94	76–82	65–80	—
	%	21 (32%)	144 (52%)	44 (72%)	0.042
Charlson score	Mean (SD)	1.7 (2.2)	2.3 (2.1)	3.6 (2.8)	<0.001
	95% CI	1.1–2.2	2.0–2.5	2.9–4.3	—
Time to operation/h	Mean (SD)	18.1 (1.4)	17.2 (0.8)	23.3 (2.3)	0.041
	95% CI	15.2–21	15.7–18.7	18.7–27.9	—

Table 2: Mortality and nursing care dependence of ICU length of stay. ∗: survivors. For all tests statistical significance was assumed at $p \leq 0.05$.

	nICU	sICU	pICU	p = sICU/pICU
In-hospital mortality	0 (0)	9 (3%)	16 (26%)	<0.001
6-month mortality*	4 (6.1%)	48 (18%)	29 (48%)	<0.001
12-month mortality*	9 (15.5%)	60 (26%)	33 (59%)	<0.001
6-month nursing-care need*	22 (42%)	123 (67%)	23 (85%)	*0.073*
12-month nursing-care need*	16 (43%)	101 (66%)	16 (84%)	*0.123*

Table 3: Multivariate analysis of independent risk factors for in-hospital mortality (IHM), 6-month mortality (6 MM), and 12-month mortality (12 MM). OR: odds ratio; CI: confidence interval; BMI: body mass index.

Variables Point of analysis	OR IHM	OR 6 MM	OR 12 MM	95% CI IHM	95% CI 6 MM	95% CI 12 MM	p value IHM	p value 6 MM	p value 12 MM
Age	0.980	1.031	1.032	0.919–1.004	0.990–1.073	0.994–1.072	0.529	0.145	0.096
Gender	1.080	0.582	0.653	0.330–3.534	0.304–1.115	0.394–1.223	0.899	0.103	0.184
Barthel index	1.000	0.997	0.992	0.979–1.021	0.984–1.009	0.980–1.004	0.983	0.594	0.173
ASA	3.085	2.147	2.160	1.059–8.985	1.190–3.873	1.241–3.758	**0.039**	**0.011**	**0.006**
Charlson index	1.048	1.160	1.196	0.847–1.296	1.013–1.328	1.050–1.362	0.666	**0.032**	**0.007**
BMI	0.993	1.001	1.003	0.978–1.007	0.991–1.012	0.993–1.013	0.327	0.830	0.557
Time until operation	1.001	1.002	1.000	0.969–1.003	0.982–1.023	0.980–1.020	0.976	0.826	0.988
ICU cohort	20.493	3.221	2.112	5.835–71.981	1.792–5.793	1.235–3.614	**0.000**	**0.000**	**0.006**
Constant	0.000	0.001	0.003	—	—	—	0.019	0.002	0.005

impairment ($N = 8$), and infection ($N = 9$) as further numerous events demanding prolonged ICU treatment. Analytic separation of the underlying reasons is given in Table 4.

Following the further clinical course of these 61 patients, 11 (18%) of them received at least transient CVVHDF and 25 (41%) received IVM. In-hospital mortality showed to be 82% in the CVVHDF group and 68% in the IVM group. The 6-month mortality (82% versus 88%) and 12-month mortality (91% versus 92%) ranged in both groups at equal levels without displaying statistical significance. Amounts of 100% are displayed concerning the 6-month and 12-month nursing-care need (Table 5).

Table 4: Reasons for admission to ICU in pICU cohort.

Reasons for ICU treatment > 3 days	Number of patients
Cardiac arrhythmia	5
Cardiac ischemia	8
Cardiac failure	4
Renal failure	8
Cholezystitis/cholangitis	3
Respiratory failure	10
Infection	9
Bowel pathology with need for surgical intervention	6
Epilepsy	1
Operative revision of surgical complication	2
Hepatic failure	1
Postoperative anemia/impaired coagulation	4

Table 5: Mortality and nursing-care need after different assessments in pICU cohort. ∗: survivors.

	Need for renal filtration	Need for invasive ventilatory management
Number of patients	$N = 11$	$N = 25$
In-hospital mortality	9 (82%)	17 (68%)
6-month mortality*	9 (82%)	22 (88%)
12-month mortality*	10 (91%)	22 (92%)
6-month nursing-care need*	2 (100%)	3 (100%)
12-month nursing-care need*	1 (100%)	2 (100%)

4. Discussion

With this prospective observational trial, we aimed to investigate long-term outcomes of geriatric hip-fracture patients who had had prolonged treatment in an ICU, particularly with regard to those undergoing invasive ventilation and renal filtration.

There are plenty of studies published that have focused on the meticulous demands of geriatric trauma patients in the last few years. Differentiated outcome data concerning geriatric hip-fracture patients, especially following invasive ventilation and hemodiafiltration due to acute lung failure or renal failure, did not exist for this special kind of cohort.

We know that, following hospital discharge, elderly patients are 2.3 times more likely to die in the long term compared to a similar age group in the general population [17]. A recent study dealing with the long-term outcome of elderly, critically ill patients showed 1-year mortalities after ICU treatment in 76% of unplanned geriatric trauma patients and 46% in planned orthopedic patients [18]. This fits our results of unplanned geriatric trauma patients in the pICU cohort, showing a 1-year mortality rate of 59%.

Most studies do not differentiate between short- and long-term ICU treatment, very likely because the admission diagnoses of most collectives are composed inhomogeneously, displaying the ICU stay itself as a joint feature. Like mentioned above, we subdivided the ICU collective into sICU and pICU cohorts. This decision was made because we saw a great difference in the underlying ICU treatment indications in these 2 groups. Patients in the sICU cohort were often admitted for a short period of postoperative inotropic support or with postoperative bleeding with a need for transfusion due to the intake of blood-thinning medications. Admission diagnoses in the pICU group often required more extensive care, as shown in Table 4.

Plenty of confounders influence the outcome of geriatric hip-fracture patients. Reducing the time between admission and operative treatment is seen as one important factor for improving survival. There are many articles that have assessed this, and a consensus has been agreed upon that a delay of more than 48 hours is unfavorable to survival [19, 20]. Some new studies focusing on 30-day mortality after adjusting for well-known risk factors, such as age, comorbidities, and gender, could show an elevated mortality following more than 12 hours of delay to surgery [21] or even an elevated 90-day mortality following a delay of more than 24 h [22]. As mentioned in Section 3, all patients underwent operative treatment for hip-related fracture in between the first 12–24 h. The pICU cohort was operated on with a slight but significant delay compared to the sICU cohort (17.2 ± 0.8 h versus 23.3 ± 2.3 h, $p = 0.041$). Thus, this significance may influence mortality rates in between our groups, even though this difference of a few hours doubtfully can be considered to display clinical relevance.

As expected, CCI was significantly higher in the pICU cohort, and higher CCI presented as an independent risk factor for higher 6- and 12-month mortality in performed multivariate analysis (Table 3). This higher level of comorbidities is well known to be associated with poorer outcomes in hip-fracture patients [23]. As obese and old patients are known to be more likely to develop adverse outcomes following a primary total-hip replacement, BMI was taken into account as well. Patients of all groups showed rather normal weight or underweight, displaying no statistical significance. The variables age, ASA score, BI, and gender in nICU, sICU, and pICU cohorts showed no statistically significant differences as well.

Apart from all these known confounders for adverse outcomes, we assume that 1 further, huge factor of influence for prolonged ICU treatment was displayed by the demand of ICU-dependent procedures like invasive ventilation or hemodiafiltration.

Particularly, pulmonary complications and renal failure due to a preexisting chronic failure appeared to be severe and life-threatening complications in geriatric trauma patients. Some prospective studies focusing on the influence of age on the outcome of mechanically ventilated elderly patients showed that age has an important effect on the outcome of mechanically ventilated patients [24, 25]. In our collective, in-hospital mortality occurred in 68% of patients with mechanical-ventilation-dependent respiratory complications. This impressively illustrates the fatal consequence of this "third hit," following trauma as a "first hit" and operative treatment as a "second hit." Ninety-two percent of these patients died within the first year after admission, and all survivors showed a need for nursing care after 12 months.

Concerning renal failure, recent epidemiological studies have reported an association between reduced glomerular filtration rate and increased risk of death and cardiovascular events [26], as well as the association between renal impairment, frailty, and quality of life. Elderly people with chronic renal insufficiency are known to have a high prevalence of frailty, which may signal their risk for progression to adverse health outcomes [27]. Irrespective of this known data, the finding that only 1 out of 11 patients undergoing hemodiafiltration during ICU stay in our collective survived the first year underlines the severe prognostic character of this procedure.

After all, keeping in mind that only 8% of patients with invasive ventilatory management and 9% of patients undergoing CVVHDF survived the first year—and none of them survived without nursing-care need—prognosis in cases of such complications worsens remarkably. Over the years, plenty of studies have confirmed that the majority of patients do not wish to survive if they lose their independence, if they become a burden on their families, or if they are unable to retain their capacity to think clearly [28, 29]. A current empirical analysis showed that if treatment is invasive and the predicted outcome is survival with severe functional impairment or cognitive impairment, 74.4% and 88.8% of patients surveyed, respectively, would not choose treatment [30]. There is a bright recognition that the burden of the proposed treatment and the probability of adverse outcomes should be specifically discussed with relatives or legal representatives when talking about end-of-life decisions in the course of intensive-care therapy [31]. Particularly, long-term results after invasive ventilation or hemodiafiltration during acute-care treatment were disastrous in our cohort. These data have to be taken into account, since short-term survival is probably not the most important factor considered when making treatment decisions in this vulnerable cohort of geriatric trauma patients. Clinicians, as well as relatives, should be aware that a patient's appraisal about what constitutes an acceptable long-term outcome may change with advancing age.

The present study has some limitations: Cohorts requiring CVVHDF and IVM were small and preexisting medical conditions and admission diagnoses were manifold. Further, because of different healthcare conceptions in different European countries (and even between different provinces in Germany), a comparison of duration of ICU stay and hospitalization period with other studies is not reasonable overall. Finally, due to the high mortality rate after 1 year, the claimed 1-year nursing-care status is certainly emphasizing a worse outcome but is not satisfactorily valid.

However, for ICU treatment extending past the normal postoperative observational period of 1 to 3 days, we found considerable differences in mortality and nursing-care need after 6 months and 1 year. Particularly, patients requiring CVVHDF or IVM had disastrous long-term results.

Data dealing with outcome parameters concerning patients obtaining CVVHDF- and IVM-dependent complications remain sparse, but the current investigation adds information that might be helpful in decision making serving this vulnerable patient cohort.

Disclosure

Daphne Eschbach is responsible on behalf of the authors.

Conflict of Interests

The authors declare that there were no further financial and personal relationships with other people or organizations that could inappropriately influence (bias) their work like employment, consultancies, stock ownership, honoraria, paid expert testimony, patent applications/registrations, or grants or other funding (like National Institutes of Health (NIH), Welcome Trust, or the Howard Hughes Medical Institute (HHMI)).

Authors' Contribution

All authors declare that they participated in the collection of data, analysis, interpretation, and writing of the paper and that they have approved the final version.

Acknowledgment

The authors thank their study nurse, A. Dersch, for being a great logistical support.

References

[1] K. Kinsella and V. A. Velkoff, *An Aging World*, Series P95/01-1, US Census Bureau, Washington, DC, USA, 2001.

[2] United Nations, Department of Economic and Social Affairs, and Population Division, "World population ageing 2013," Tech. Rep. ST/ESA/SER.A/348, United Nations, Department of Economic and Social Affairs, Population Division, 2013.

[3] S. M. White and R. Griffiths, "Projected incidence of proximal femoral fracture in England: a report from the NHS Hip Fracture Anaesthesia Network (HIPFAN)," *Injury*, vol. 42, no. 11, pp. 1230–1233, 2011.

[4] M. R. Law, N. J. Wald, and T. W. Meade, "Strategies for prevention of osteoporosis and hip fracture," *British Medical Journal*, vol. 303, no. 6800, pp. 453–459, 1991.

[5] S. L. Greenspan, E. R. Myers, L. A. Maitland, N. M. Resnick, and W. C. Hayes, "Fall severity and bone mineral density as risk factors for hip fracture in ambulatory elderly," *The Journal of the American Medical Association*, vol. 271, no. 2, pp. 128–133, 1994.

[6] Network GR, "Acute Care Hip Fracture Clinical Pathway," October 2011, http://www.gtarehabnetwork.ca/clinical-care-guidelines-hip-fracture.

[7] SIGN, *Management of Hip Fracture in Older People—A National Clinical Guideline*, Scottish Intercollegiate Guidelines Network, Edinburgh, UK, 2009.

[8] C. L. Sprung, D. Geber, L. A. Eidelman et al., "Evaluation of triage decisions for intensive care admission," *Critical Care Medicine*, vol. 27, no. 6, pp. 1073–1079, 1999.

[9] E. Simchen, C. L. Sprung, N. Galai et al., "Survival of critically ill patients hospitalized in and out of intensive care units under paucity of intensive care unit beds," *Critical Care Medicine*, vol. 32, no. 8, pp. 1654–1661, 2004.

[10] G. Joynt, C. Gomersall, P. Tan, A. Lee, C. Cheng, and E. Wong, "Prospective evaluation of patients refused admission to an intensive care unit: triage, futility and outcome," *Intensive Care Medicine*, vol. 27, no. 9, pp. 1459–1465, 2001.

[11] G. Djaiani and S. Ridley, "Outcome of intensive care in the elderly," *Anaesthesia*, vol. 52, no. 12, pp. 1130–1136, 1997.

[12] G. E. Rosenthal, P. J. Kaboli, M. J. Barnett, and C. A. Sirio, "Age and the risk of in-hospital death: insights from a multihospital study of intensive care patients," *Journal of the American Geriatrics Society*, vol. 50, no. 7, pp. 1205–1212, 2002.

[13] D.-A. Eschbach, L. Oberkircher, C. Bliemel, J. Mohr, S. Ruchholtz, and B. Buecking, "Increased age is not associated with higher incidence of complications, longer stay in acute care hospital and in hospital mortality in geriatric hip fracture patients," *Maturitas*, vol. 74, no. 2, pp. 185–189, 2013.

[14] R. Marks, "Hip fracture epidemiological trends, outcomes, and risk factors, 1970–2009," *International Journal of General Medicine*, vol. 3, pp. 1–17, 2010.

[15] F. Hu, C. Jiang, J. Shen, P. Tang, and Y. Wang, "Preoperative predictors for mortality following hip fracture surgery: a systematic review and meta-analysis," *Injury*, vol. 43, no. 6, pp. 676–685, 2012.

[16] S. Ewig, N. Birkner, R. Strauss et al., "New perspectives on community-acquired pneumonia in 388 406 patients: results from a nationwide mandatory performance measurement programme in healthcare quality," *Thorax*, vol. 64, no. 12, pp. 1062–1069, 2009.

[17] A. Mukhopadhyay, B. C. Tai, K. C. See et al., "Risk factors for hospital and long-term mortality of critically ill elderly patients admitted to an intensive care unit," *BioMed Research International*, vol. 2014, Article ID 960575, 10 pages, 2014.

[18] V. Pavoni, L. Gianesello, L. Paparella, L. T. Buoninsegni, E. Mori, and G. Gori, "Outcome and quality of life of elderly critically ill patients: an Italian prospective observational study," *Archives of Gerontology and Geriatrics*, vol. 54, no. 2, pp. e193–e198, 2012.

[19] N. Simunovic, P. J. Devereaux, S. Sprague et al., "Effect of early surgery after hip fracture on mortality and complications: systematic review and meta-analysis," *Canadian Medical Association Journal*, vol. 182, no. 15, pp. 1609–1616, 2010.

[20] T. Shiga, Z. Wajima, and Y. Ohe, "Is operative delay associated with increased mortality of hip fracture patients? Systematic review, meta-analysis, and meta-regression," *Canadian Journal of Anesthesia*, vol. 55, no. 3, pp. 146–154, 2008.

[21] C. P. Bretherton and M. J. Parker, "Early surgery for patients with a fracture of the hip decreases 30-day mortality," *Bone and Joint Journal B*, vol. 97, no. 1, pp. 104–108, 2015.

[22] A. M. Nyholm, K. Gromov, H. Palm, M. Brix, T. Kallemose, and A. Troelsen, "Time to surgery is associated with thirty-day and ninety-day mortality after proximal femoral fracture: a retrospective observational study on prospectively collected data from the Danish Fracture Database Collaborators," *The Journal of Bone & Joint Surgery—American Volume*, vol. 97, no. 16, pp. 1333–1339, 2015.

[23] S. Sakan, D. B. Pavlovic, M. Milosevic et al., "Implementing the Surgical Apgar Score in patients with trauma hip fracture," *Injury*, vol. 46, supplement 6, pp. S61–S66, 2015.

[24] M. D. Zilberberg and S. K. Epstein, "Acute lung injury in the medical ICU: comorbid conditions, age, etiology, and hospital outcome," *American Journal of Respiratory and Critical Care Medicine*, vol. 157, no. 4, part 1, pp. 1159–1164, 1998.

[25] J. P. Nunn, J. S. Milledge, and J. Singaraya, "Survival of patients ventilated in an intensive therapy unit," *British Medical Journal*, vol. 1, pp. 1525–1527, 1979.

[26] L. G. Glynn, D. Reddan, J. Newell, J. Hinde, B. Buckley, and A. W. Murphy, "Chronic kidney disease and mortality and morbidity among patients with established cardiovascular disease: a West of Ireland community-based cohort study," *Nephrology Dialysis Transplantation*, vol. 22, no. 9, pp. 2586–2594, 2007.

[27] M. G. Shlipak, C. Stehman-Breen, L. F. Fried et al., "The presence of frailty in elderly persons with chronic renal insufficiency," *American Journal of Kidney Diseases*, vol. 43, no. 5, pp. 861–867, 2004.

[28] T. R. Fried, E. H. Bradley, V. R. Towle, and H. Allore, "Understanding the treatment preferences of seriously ill patients," *The New England Journal of Medicine*, vol. 346, no. 14, pp. 1061–1066, 2002.

[29] G. E. Mead, S. T. O'Keeffe, C. I. Jack, A. M. Maèstri-Banks, J. R. Playfer, and M. Lye, "What factors influence patient preferences regarding cardiopulmonary resuscitation?" *Journal of the Royal College of Physicians of London*, vol. 29, no. 4, pp. 295–298, 1995.

[30] L. P. Scheunemann, T. V. Cunningham, R. M. Arnold, P. Buddadhumaruk, and D. B. White, "How clinicians discuss critically ill patients' preferences and values with surrogates? an empirical analysis," *Critical Care Medicine*, vol. 43, pp. 757–764, 2015.

[31] A. Manara, "Bespoke end-of-life decision making in ICU: has the tailor got the right measurements?" *Critical Care Medicine*, vol. 43, no. 4, pp. 909–910, 2015.