



Osteoarthritis is associated with increased failure of proximal femoral fracture fixation

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Abstract

Purpose The purpose of this study was to evaluate whether the presence of hip osteoarthritis at the time of hip fracture increases treatment failure rates when using either a sliding hip screw (SHS) or proximal femoral nail (PFN) for fracture fixation.

Methods A retrospective study of a consecutive series of 455 women and 148 men (median age, 83.8 years) treated with SHS or PFN was performed. Osteoarthritis was evaluated based on pre-operative radiographs using the Kellgren and Lawrence grading system. Treatment failure, which was defined as non-union, avascular necrosis, backing out of the implant, cut out of the proximal screws, peri-prosthetic fracture, implant breakage, or conversion to hemi- or total hip arthroplasty, was evaluated for a follow-up period of four to seven years. Optimal placement of the implant (tip-apex distance (TAD) and 3-point fixation) and the effects of age, sex, the quality of reduction, implant type, fracture stability, fracture type, and time to failure were considered confounders of the relationship between failure and osteoarthritis (OA).

Results Among the 32 cases (5.3%) of treatment failure, 12 (2%) showed evidence of osteoarthritis. After controlling for age, sex, the quality of reduction, implant type, fracture stability, fracture type, and TAD, osteoarthritis was associated a greater than threefold increase in treatment failure compared with that of patients without pre-operative evidence of osteoarthritis (OR, 3.26; 95% CI, 1.4–7.65; $P=0.006$).

Conclusions After adjusting for potential confounding factors, radiographic evidence of hip osteoarthritis at the time of hip fracture increases the incidence of treatment failure.

Keywords Hip · Neck of femur · Fracture · Osteoarthritis · Treatment · Failure

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Introduction

Failure of appropriate treatment of proximal femoral fractures results in major costs to both the patient and the health care system [1]. Hip fractures constitute a large socioeconomic burden, being responsible for an estimated loss of 1.75 million disability-adjusted life years, representing 1.4% of the total health care burden in established market economies [2]. Hip fractures are associated with a 12-month mortality rate of 22 to 29%, and most patients who survive the injury are not able to return to their pre-injury levels of function and independence [3].

Two types of implants are commonly used for hip fracture fixation: the sliding hip screw (SHS) and the proximal femoral nail (PFN). The rates of treatment failure using these implants are highly variable, ranging between 1.5 and 56% [4, 5]. The possible effect of coexisting hip osteoarthritis, another common hip pathology, on the risk of treatment failure has not previously been evaluated.

Based on our clinical experience, we hypothesized that stiffness and restricted range of motion in osteoarthritic hips would increase the strain across the fracture site and fixation, disrupting the healing process and increasing the risk of treatment failure. Local inflammatory substances could hypothetically further inhibit the healing process. Given that an improved understanding of the predictors of failure may influence pre- and intra-operative treatment decisions and whether coexisting OA is associated with failure of fixation, the surgeon's pre-operative decisions regarding the implant type and consideration of the use of arthroplasty to manage certain fractures may be altered.

The aim of the present study was to evaluate whether hip osteoarthritis at the time of hip fracture increases the incidence of treatment failure for SHS and PFN implants. The effects of the following secondary risk factors were also investigated: age, sex, the quality of reduction, implant type, fracture stability, fracture type, tip-apex distance (TAD), and 3-point fixation.

Materials and methods

We conducted a retrospective observational study of all consecutive patients with hip fractures treated using either an SHS or PFN at three tertiary hospitals in Western Australia, between January 1, 2002, and December 31, 2004, including a follow-up period of four to seven years. Cases were identified from surgical databases and implant tracking records using “SHS” and “PFN” as search terms. The inclusion criteria were availability of clinical data and adequate pre- and post-operative anterior-posterior and lateral hip radiographs. Patients with diaphyseal fractures, forms of hip arthritis other than osteoarthritis, pathological fractures other than those caused by osteoporosis, and concomitant fractures proximal or distal to the hip were excluded. Patients under the age of 50 years were excluded. Ethics approval was obtained from the Western Australia Department of Health Human Research Ethics Committee.

Pre-operative radiographs were reviewed using the Picture Archiving Computer System (PACS). The severity of osteoarthritis was classified using the Kellgren and Lawrence grading system, with “0” being indicative of “no osteoarthritis” and a grade of “4” being indicative of “severe osteoarthritis.” Hips classified as grade 2 or higher were defined as having osteoarthritis [6].

Fracture patterns were classified using the Orthopedic Trauma Association (OTA) guidelines [7], with fracture stability being determined according to the Garden classification [8] and Evans' classification, as modified by Jensen et al. [9]. Garden type 1 and 2 fractures and Jensen type 1 and 2 fractures were classified as stable fractures, whereas Garden type 3 and 4 fractures and Jensen type 3, 4, and 5 fractures were classified as unstable.

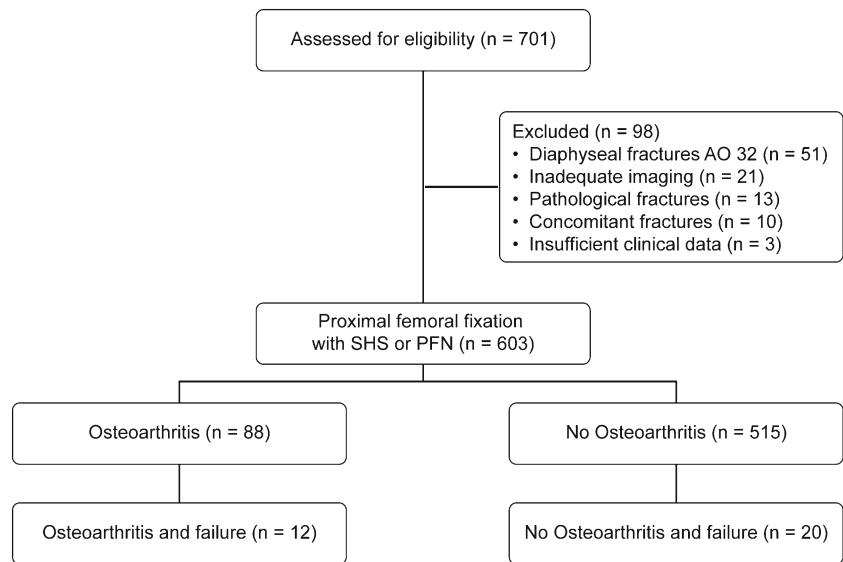
The quality of reduction was graded as good, acceptable, or poor according to Baumgaertner et al. [10]. Fixation at the femoral head was graded based on the TAD according to Baumgaertner et al. [10] and was classified as satisfactory if < 25 mm [11]. To correct for radiographic magnification, the diameter of the lag screw (10.5 mm) was used. “Three-point” proximal fixation was examined in the PFN group. The position of the lag screw at the lateral femoral cortex was classified as satisfactory when the screw was in contact with or protruding from the lateral femoral cortex, and the position of the tip of the proximal nail/end-cap was classified as satisfactory if it was in contact with or protruding beyond the cortex at the greater trochanter [12]. These assessments were performed by an orthopedic fellow or registrar (CG, CJ, and CW).

Treatment failure was identified based on the final post-operative follow-up radiographs and included the following: non-union, avascular necrosis, backing out of the implant, cut out of the proximal screws, peri-prosthetic fracture, implant breakage, or conversion to hemi- or total hip arthroplasty. All radiographs were examined by a single observer (CG). To calculate the inter-rater reliability of the Kellgren and Lawrence classification, all cases of osteoarthritis were reassessed by the senior author (PY). When the grading of osteoarthritis differed among the observers, the grade provided by the senior author (PY) was used in the analysis.

The standardized follow-up protocol for all patients included assessment in outpatient clinics at six weeks, six month, and one year post surgery with a clinical examination and radiographs. In the event of delayed or non-union, patients received appropriate investigations as guided by the clinical presentation. After 12 months, only patients who had clinical or radiographic concerns were followed up and reviewed.

All statistical analyses were performed using Stata 12.0 (StataCorp, College Station, Texas, USA). Parametric data are presented as the means and standard deviations, whereas data that were not normally distributed are presented as medians and interquartile ranges. The differences between the groups were assessed using chi-square tests (categorical data) or *t* tests (continuous data). Factors exhibiting a univariate relationship to failure of > 0.2 were included in a multivariate logistic regression. Fracture type (31-A compared with 31-B) was significantly related to implant type (with only SHS being used for the fixation of 31-B-type fractures); thus, an interaction term between these two variables was employed in the final model. Logistic regression analysis was undertaken for the entire group as well as trochanteric hip fractures alone (31-A1, 31-A2, 31-A3) and subcapital fracture alone (31-B1, 31-B2, 31-B3). The applied statistical techniques included Cohen's kappa for calculating the inter-rater reliability of osteoarthritis classification. The time to failure was compared between groups of patients with and without pre-operative osteoarthritis using Cox proportional hazard regression modeling. A *P* value ≤ 0.05 was considered significant.

Fig. 1 Patient characteristics and flow



Results

Population demographics

There were 701 eligible patient records identified. Among these records, 51 fractures were diaphyseal, 21 showed inadequate imaging, 13 showed pathological fractures, ten showed concomitant fractures, and three showed insufficient clinical data for analysis. Therefore, a total of 603 patients formed the study group (Fig. 1). There were 497 SHSs and 106 PFNs. PFNs were both short and long nails.

The cohort consisted of 455 women and 148 men (median age 83.8, interquartile range (IQR) 78.1 to 89.1), with a median age of 85.1 years (IQR 79.09 to 89.5) for the women and 79.7 years (IQR 74.7 to 87.4) for the men. The distribution of the observed fracture patterns, failure, and the presence of osteoarthritis and failure is reported in Fig. 2. The fracture patterns and the implant types used for treatment are reported in Fig. 3. Treatment failure, an example seen in Fig. 4, was identified in 32 (5.3%) cases, including 20 without evidence of osteoarthritis and 12 with evidence of osteoarthritis. The causes of failure included cut out (22 cases), backing out of the implant (2 cases), peri-prosthetic fracture (5 cases), and avascular necrosis (3 cases). In the PFN population, 11 patients underwent revision surgery (3 hemiarthroplasty cases, 3 revision open reduction internal fixation operations, 5 Girdlestone procedures/no action taken). In the SHS population, 21 patients underwent revision surgery (6 total hip replacements, 6 hemiarthroplasty cases, 4 revision open reduction internal fixation operations, 5 Girdlestone procedures/no action taken). During the follow-up period, there were 63 in the PFN population and 298 patients in the SHS population that died.

Variables associated with treatment failure

The factors associated with treatment failure are outlined in Table 1. After controlling for age, sex, the quality of reduction, implant type, fracture stability, fracture type, and TAD, osteoarthritis was associated with a greater than threefold increase in treatment failure compared with that of patients without pre-operative evidence of osteoarthritis (OR, 3.26; 95% CI, 1.4–7.65; *P* = 0.006) (Table 2). When 31-A-type fractures were assessed alone and the above factors were controlled for, the risk associated with osteoarthritis remained comparable (Table 3). Only seven of the B-type fractures failed, and no significant association was observed between any of the factors included in this multivariate analysis (OR OA, 2.58; 95% CI, 0.35–18.88; *P* = 0.35).

Other factors that were significantly associated with failure included TAD and implant type (Table 2). Patients with 31-B- or 31-A-type fractures who received a PFN exhibited

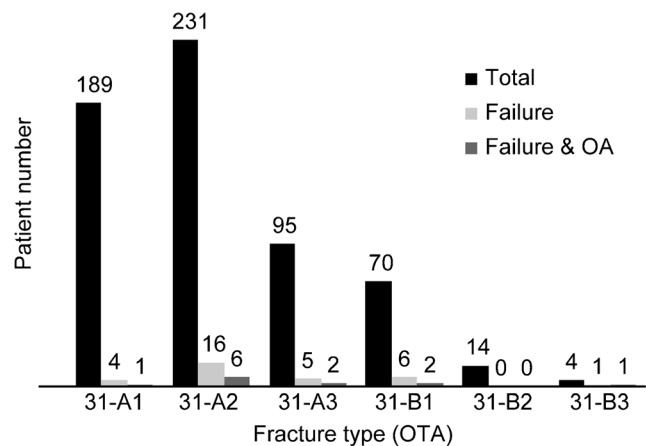


Fig. 2 Demographics of fracture patterns, failure, and failure with osteoarthritis (OA)

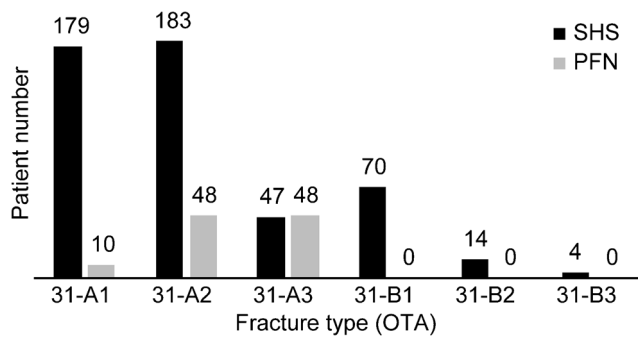
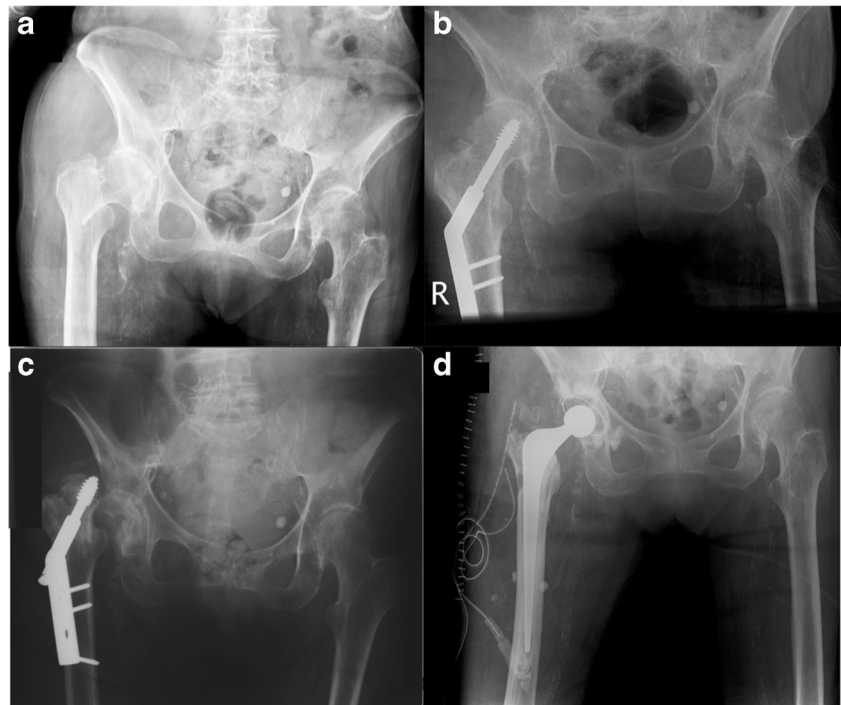


Fig. 3 Demographics of fracture patterns and implants

significantly higher odds of failure in the multivariate analysis than that of patients with 31-A-type fractures fixed with an SHS. When “cut out of proximal screws” and “backing out” were employed as primary determinants of treatment failure, the risk associated with osteoarthritis remained comparable (OR, 4.17; 95% CI, 1.54–11.27; $P=0.005$).

Among patients with osteoarthritis, the mean time to failure for both types of implants was 106 days (range, 6–302 days; std. dev., 97.07 days), with a mean time of 139 days (range, 15–302 days; std. dev., 104.57 days) being observed for SHS implants and 59 days (range, 6–179 days; std. dev., 69.4 days) for PFNs. Among patients without osteoarthritis, the comparable mean times were 182 days (range, 15–1055 days; std. dev., 266.2 days) for the overall group, 166.57 days (range, 20–1055 days; std. dev., 268.67 days) for the SHS group, and 209.5 days (range, 15–753 days; std. dev., 282.95 days) for the PFN group. No between-group differences were noted (hazard ratio, 1.27; 95% CI, 0.61–2.68; $P=0.52$).

Fig. 4 Osteoarthritis (OA) and failure of fixation. **a** 31-A1 hip fracture and OA, **b** SHS fixation, **c** Failure of fixation via cut out, and **d** revision total hip replacement



Univariate regression analysis demonstrated a trend towards an increasing failure rate with an increasing grade of osteoarthritis (OR, 1.83; 95% CI, 1.26–2.66; $P=0.005$) (Table 1). There was no association between osteoarthritis and fracture type ($P=0.547$). The inter-rater agreement in the grading of osteoarthritis was good (63.5%), with a moderate chance-adjusted kappa agreement (47.3%).

Discussion

To our knowledge, this study is the first to assess hip osteoarthritis as a predictive factor for treatment failure using SHS and PFN implants for hip fractures. We observed a greater than threefold increase in the risk of treatment failure in patients with osteoarthritis at the time of hip fracture, where osteoarthritis was quantified using the Kellgren and Lawrence grading system, compared with that of patients without osteoarthritis. The reasons for our findings are unclear, although we hypothesize that greater forces applied across the fracture site in trochanteric hip fractures could affect healing and account for the higher risk of treatment failure. When “cut out of proximal screw” and “backing out of the implant” were employed as primary determinants of treatment failure, the association between osteoarthritis and a higher risk of failure remained significant. This result was also obtained when considering only 31-A-type fractures.

The overall rates of treatment failure in patients without osteoarthritis observed in this study, of 4.2 and 10.4% for

Table 1 Factors associated with treatment failure post-PFN or SHS (univariate analyses)

Descriptor		No failure <i>n</i> = 571 (94.7%)	Failure <i>n</i> = 32 (5.3%)	Total <i>n</i> = 603	<i>P</i> value
OA	Yes	76 (86.4)	12 (13.6)	88(14.6)	< 0.001
	No	495 (96.1)	20 (3.9)	515 (85.4)	
Age (median, 25th/75th percentiles) (years)		82.4 (78.1, 89.1)	83.7 (78.9, 88.4)	82.5 (78.1, 89.1)	0.453
Gender	Male	141 (24.7)	7 (21.9)	148 (24.5)	0.718
	Female	430 (75.3)	25 (78.1)	455 (75.5)	
Quality of reduction (according to Baumgaertner)	Poor	79 (89.8)	9 (10.2)	88 (14.6)	0.057
	Mod	127 (94.1)	8 (5.9)	135 (22.4)	
	Good	365 (96.1)	32 (3.9)	380 (63)	
Implant Stability	SHS	476 (95.8)	21 (4.2)	497 (82.4)	0.01
	PFN	95 (89.6)	11 (10.4)	106 (17.6)	
TAD	Stable	294 (96.4)	11 (3.6)	305 (50.6)	0.06
	Unstable	277 (93)	21 (7)	298 (49.4)	
	< 25 mm	439 (96.7)	15 (3.3)	454 (75.3)	
Fracture classification (OTA)	≥ 25 mm	132 (88.6)	17 (11.4)	149 (24.7)	0.065
	31-A1	185 (32.4)	4 (12.5)	189 (31.3)	
	31-A2	215 (37.7)	16 (50)	231 (38.3)	
	31-A3	90 (15.8)	5 (15.6)	95 (15.8)	
	31-B1	64 (11.2)	6 (18.8)	70 (11.6)	
	31-B2	14 (2.5)	0 (0)	14 (2.3)	
	31-B3	3 (0.5)	1 (3.1)	4 (0.7)	
Lat cortex nail sticking out (PFN only <i>n</i> = 106)	Yes	79 (91.9)	7 (8.1)	86 (81.1)	0.117
	No	16 (80)	4 (20)	20 (18.9)	
Prox cortex nail sticking out (PFN only <i>n</i> = 106)	Yes	90 (89.1)	11 (10.9)	101 (95.3)	0.436
	No	5 (100)	0 (0)	5 (4.7)	
TAD (PFN only <i>n</i> = 106)	< 25 mm	75 (91.5)	7 (8.5)	82 (77.4)	0.251
	≥ 25 mm	20 (83.3)	4 (16.7)	24 (22.6)	
Three points of fixation (0 = no points of fixation; 3 = all points of fixation achieved. PFN only <i>n</i> = 106)	0	2 (100)	0 (0)	2 (1.9)	0.289
	1	5 (71.4)	2 (28.6)	7 (6.6)	
	2	25(86.2)	4(13.8)	29 (27.4)	
	3	63 (92.6)	5 (7.4)	68 (64.2)	

OA osteoarthritis, PFN proximal femoral nail, SHS sliding hip screw, TAD tip-apex distance, OTA Orthopedic Trauma Association

SHS and PNF, respectively, are similar to previously reported rates [4]. Although the rate increased to 13.6% in patients with osteoarthritis, this rate is still within the lower range of estimates of treatment failure reported in other studies [4, 5]. Our inclusion of both stable and unstable fractures could explain the lower rate of treatment failure in the present study, given that treatment failure rates are lower for stable fractures [4].

Stability [4], the quality of reduction [13], implant type [4, 12], and TAD [10, 11] were found to increase the risk of treatment failure, which is consistent with findings reported in the literature. Inadequate three-point fixation also increased failure [12]. The small sample size within the PFN subgroup (*n* = 106) did not allow a meaningful statistical analysis of whether the type of failure was associated with any specific inadequacy of proximal fixation. The lateral cortex, TAD, and reduced points of fixation exhibited a trend towards increasing the failure rate in a univariate analysis; however, upon review

in a multivariate analysis, none of these factors showed a significant relationship with failure.

Contrary to the findings of Hsueh et al. [14] indicating an increased rate of failure with age, we did not identify a modifying effect of either age or sex. This disparity could be explained by the differences in patient age between these studies.

As previously reported [15], cut out of screws was found to be the predominant cause of failure, regardless of osteoarthritis status. Although the small number of patients in our study group who experienced treatment failure of this type limited further subgroup analysis, our preliminary findings warrant further investigation to establish the role of osteoarthritis in the higher rate of cut out-related failure.

Four of the five peri-prosthetic fractures in our study group occurred in patients without osteoarthritis. We anticipated that this restriction would lead to greater strain on the fractures and their fixation and therefore result in higher rates of peri-

Table 2 Factors associated with treatment failure post-PFN or SHS (multivariate analyses)

Descriptor		AOR (95% CI)	P value
OA	No	1	0.006
	Yes	3.26 (1.40, 7.65)	
Age		1.03 (0.98, 1.08)	0.25
Gender	Male (reference)	1	0.59
	Female	1.30 (0.51, 3.31)	
Quality of reduction (according to Baumgaertner)	Good/Mod (reference)	1	0.051
	Poor	2.42 (0.996, 5.91)	
Stability	Stable (reference)	1	0.10
	Unstable	2.06 (0.86, 4.88)	
TAD	< 25 mm (reference)	1	< 0.001
	≥ 25 mm	4.37 (2.0, 9.48)	
Implant/fracture type interaction	31 A-type# and SHS (ref)		
	31 B-type# and SHS	3.88 (1.33, 11.27)	0.013
	31 A-type and PFN	2.83 (1.10, 7.34)	0.031

There were no 31-B #s with PFN

AOR adjusted odds ratio, OA osteoarthritis, PFN proximal femoral nail, SHS sliding hip screw, TAD tip-apex distance

prosthetic fractures. It is possible that the presence of osteoarthritis could lead to a painful hip, restricting patients' activities and reducing the applied mechanical strain. Further research is needed to determine whether osteoarthritis actually exerts a protective effect against peri-prosthetic fracture.

Fracture classification is a known risk factor for failure [16, 17], as observed in the present study. Patients with a 31-A-type fracture fixed with a PFN exhibited significantly higher odds of failure in the multivariate analysis than that of patients with a 31-A-type fracture fixed with an SHS. This finding may be due to the use of PFN in more unstable fracture types; however, the rate of PFN failure has been shown to be greater than that of SHS [4, 12]. Complication rates are similar between short and long nails [18], which should be taken into

account when considering the failure rates in the PFN population, given both short and long nails were used.

In addition, 31-B fractures are associated with higher rates of failure of internal fixation, as confirmed by the findings of the present study (8% 31-B and 4.86% 31-A) [19, 20]. Only seven of the 31-B fractures failed, with no significant association being observed between any of the factors included in the multivariate analysis.

The use of SHSs and PFNs to treat 31-A- and 31-B-type fractures is common in most institutions across the USA, Europe, and Australia. We recognize that regional differences in fracture management exist; however, performing data collection using implant type rather than fracture classification did not bias patient selection.

Table 3 Factors associated with treatment failure in 31-A1, A2, and A3 fractures (multivariate analyses)

Descriptor		AOR (95% CI)	P value
OA	No (reference)	1	0.01
	Yes	3.49 (1.3, 9.4)	
Age		1.03 (0.98, 1.08)	0.29
Gender	Female (reference)	1	0.98
	Male	1.01 (0.35, 2.91)	
Quality of reduction (according to Baumgaertner)	Good/Mod (reference)	1	0.14
	Poor	2.13 (0.78, 5.87)	
Implant	SHS (reference)	1	0.05
	PFN	2.61 (0.98, 6.91)	
Stability	Stable (reference)	1	0.03
	Unstable	3.23 (1.09, 9.53)	
TAD	< 25 mm (reference)	1	< 0.001
	≥ 25 mm	5.1 (2.1, 12.37)	

AOR adjusted odds ratio, OA osteoarthritis, PFN proximal femoral nail, SHS sliding hip screw, TAD tip-apex distance

Univariate regression analysis demonstrated a trend towards an increased risk of failure with an increasing osteoarthritis grade, a finding consistent with our a priori hypothesis. The small sample sizes of the patient groups meant that a meaningful statistical analysis could not be performed. However, it is possible that local inflammatory substances around an osteoarthritic joint may inhibit the healing process, independent of the degree of osteoarthritis.

To contextualize our findings, we aimed to assess whether the observed rate of osteoarthritis was representative of population estimates. A systematic review by Pereira et al. [21] identified an overall prevalence of hip osteoarthritis of 10.9%, with prevalence estimates varying widely between studies. The prevalence recorded in our study group was comparable, with 14.6% of patients having osteoarthritis at the time of hip fracture. Different associations between osteoarthritis and hip fractures have been reported, with conflicting studies reporting an overall lower risk of fracture [19], an increased risk of extra-capsular fractures [22] and the degree of osteoarthritis being associated with different fracture patterns [23]. As these studies differ in their methodology and the definition of hip osteoarthritis, interpretation of their outcomes and direct comparison with our cohort is difficult.

The present study indicates that taking extra care in fracture reduction and implant selection plus fixation is warranted when treating patients with hip fractures and osteoarthritis. There is a significant body of evidence supporting the use of arthroplasty for displaced intra-capsular fractures [24]; however, there is currently insufficient evidence that arthroplasty provides clinical advantages over internal fixation for extra-capsular hip fractures [25]. Further research is also needed to define optimal parameters of rehabilitation, such as the duration of restricted weight bearing where possible, to reduce the risk of treatment failure.

Several limitations of our study should be noted in the interpretation of its outcomes. The retrospective observational design inherently carries the possibility of bias, given that the data were obtained from three related health institutions. Although the inclusion of two types of implants and a mixture of intra-capsular and extra-capsular hip fractures increased our sample size, the power of between-group comparisons was limited by the small number of patients in each subgroup. In addition, we did not control for the loss to follow-up of patients who sustained treatment failure outside of our metropolitan area or the outer urban region in Western Australia. However, given the isolated geography of Western Australia, we anticipated that our rate of patient capture would be high compared with that of a study using similar methodology performed at other institutions across mainland Australia. We utilized the Kellgren and Lawrence grading system because it exhibits sufficient reliability for the identification and classification of hip osteoarthritis and is the most widely used system for the clinical assessment of hip osteoarthritis [26]. Our inter-rater agreement indicated that the hypothesis of randomly made determinations should be rejected.

The mechanism of injury was not accounted for, but all of our patients were > 50 years in age, with a median age of 83.8 years. It is likely that the majority of fractures resulted from low-energy injuries occurring in osteoporotic bone, for which increasing age is a risk factor [27]. Although it would be desirable to collect data on bone mineral density determined based on dual x-ray absorptiometry (DEXA) scores, this was not possible given the volume of work and limited clinical resources. In addition, it was not possible to follow all patients until radiographic union. Other factors associated with treatment failure, including pharmacological use and rehabilitation, were not considered. Larger multi-center trials should include these factors in their analyses to provide a comprehensive profile of the factors that may influence the relationship between osteoarthritis and treatment failure.

Conclusion

The results of this study support the hypothesis that radiographic evidence of hip osteoarthritis at the time of hip fracture increases the incidence of treatment failure, despite optimal treatment with ideal implants. These findings support the need for a prospective study to further assess the relationship between concomitant hip fracture and hip osteoarthritis and the factors influencing treatment failure.

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Compliance with ethical standards

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

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. Formal consent is not required for this type of study.

Informed consent Informed consent was not required for this study in accordance with the National Health and Medical Research Council (NHMRC) guidelines and Human Research Ethics Committee approval.

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