Results of femoral neck screw fixation in 112 under 65-years-old at a minimum 2 years' follow-up

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Original article

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Abstract

Introduction: Failure rates for screw fixation in femoral neck fracture in young patients are often high, with risk of aseptic femoral head osteonecrosis and non-consolidation. The present study sought to identify factors for success or failure of internal fixation according to 1) initial treatment, 2) initial reduction quality, and 3) population characteristics.

Hypothesis: The study hypothesis was that population, fracture type, initial treatment and reduction quality can predict survival.

Material and methods: A retrospective study included all cases of femoral neck fracture in under-65 year-olds treated by screwing in our center: i.e., 112 patients. Patient characteristics, time to surgery were collated; surviving patients were followed up at a minimum 24 months. Reduction quality was assessed on X-rays in 3 dimensions and cervico-diaphyseal angle.

Results: Mean follow-up was 5.3 ± 3.0 years [range, 2.0-13.6 years]. At 2 years, 23 of the 112 patients (20.5%) had developed complications: 10 osteonecroses (8.9%) and 13 non-unions (11.6%). Known hip osteonecrosis risk factors showed no significant association with survival. Failure rates were significantly higher in unstable (Garden ≥3) than stable (Garden ≤ 2) fracture: HR = 2.77 [95% CI: 1.09 - 7.02]; p = 0.025. There was no significant association with time to treatment (≤ 6 hours): HR = 1.08 [95% CI: 0.46 - 2.54]; p = 0.86. On 2-year radiographs, mean shortening on the Z axis was 12.3 ± 4.8 mm [-0.7 to 26.2], 8.5 ± 5.0 mm [-6.8 to 23.9] on the X axis, and 6.4 ± 6.1 mm [-6.3 to 25.3] on the Y axis. There was a significant negative correlation between Z shortening and HOOS pain component (r = - 0.38; p = 0.005), a non-significant negative correlation with quality of life (r = - 0.20; p = 0.16), and a significant negative correlation with sports activity (r = - 0.28; p = 0.039).

Conclusion: The present series showed lower rates of complications and of arthroplasty than in the literature. Internal fixation seemed to be indicated even at an interval of 6 hours or more.

Level of evidence: IV, retrospective study

Key words: femoral neck fracture, osteonecrosis, young patient, mortality, complication, time to surgery

1. INTRODUCTION

Annual incidence of proximal femoral fracture in over-20 year-olds is 170/100,000 in females and 62/100,000 in males [1], with 94,563 fractures in France as a whole in 2017. About 35% occur in under-70 year-old women and 50% in under-70 year-old men [2]. Femoral neck fractur in the non-geriatric population is a case apart, and most often involves high-energy trauma (work or road accident) in active subjects with high functional demand. Treatment is internal fixation by triangular screwing, performed in emergency to conserve femoral head integrity, reduce risk of necrosis and allow return to previous activities [3–6].

However, failure rates are often high, the main complications being aseptic osteonecrosis (AON) of the femoral head, non-consolidation [7] and severe femoral neck shortening [8,9], with possible long-term consequences [10]. Therefore, in the absence of consensus on management [11], we sought to analyze the series in our traumatology department, with a view to improving management.

A retrospective study was conducted to identify factors for success or failure of internal fixation according to 1) initial treatment, 2) initial reduction quality, and 3) population characteristics.

The study hypothesis was that population, type of fracture, initial treatment and reduction quality are predictive of survival.

2. MATERIAL AND METHODS

2.1 Population

A retrospective study included all cases of femoral neck fracture in under-65 year-olds treated by femoral neck screw fixation in our center between January 1, 2006 and December 31, 2016. (In our center, over-65 year-olds are managed by hip replacement for this type of fracture).

All patients were adults, with femoral neck fracture treated by femoral neck screwing. Patients with bilateral or pathologic fracture or lacking pre- or post-operative or follow-up radiographs were excluded. The flowchart is shown in figure1.

Mean age at fracture was 53.04 ± 10.9 years [range, 21-65 years]. There were 55 men (49.1%) and 57 women (50.9%). 107 (95.7%) were autonomous, living at home, and 4.3% were dependent, living in an institution. All had unilateral fracture, treated surgically. Mean hospital stay was 5.8 ± 4.6 days [1-29].

Fifteen patients (13.4%) had Pauwels 1 fracture, 57 (50.9%) Pauwels 2, and 40 (35.7%) Pauwels 3. On the Garden classification, 30 (26.8%) were Garden 1, 21 (18.8%) Garden 2, 38 (33.9%) Garden 3 and 23 (20.5%) Garden 4.

Concerning risk factors, 14 patients (12.5%) had undergone corticosteroid therapy, including 8 (57%) for >3 months; 20 (17.9%) had abnormal alcohol consumption occasionally and 18 (16.1%) chronically. 37 patients (33%) were active smokers and 3 (2.7%) had ceased for at least 6 months.

Mean time to treatment was 11.0 ± 21.5 hours [0.3-144], and less than 6 hours in 73 cases (65.2%).

Trauma mechanism was high energy (mainly fall while skiing, >2 meter fall or road accident) in 35 cases (31.25%).

2.2 Treatment and data collection

Our center had the advantage of having a large volume of young patients with femoral neck fracture, being the only local center performing surgery around the clock. Cooperative under-65 year-olds in good general health systematically receive surgical treatment as quickly as possible, within 6 hours if feasible. In Garden 3 and 4 fracture, the procedure consisted in reduction by external maneuver on an orthopedic table followed by triangular internal fixation using 3 cannulated partially-threaded 7-mm screws under fluoroscopic control; Garden 1 and 2 fractures were treated by in-situ screwing [4,5]. Postoperatively, weight-bearing was not allowed on the operated limb for 90 days. Patients were followed up at 1 month, 3 months, 6 months and 2 years to screen for complications and, in case of secondary displacement, propose suitable surgical revision.

Patient characteristics and time to surgery were collected from files. Surviving patients were followed up in consultation, or families were contacted in case of death. Minimum follow-up was 24 months. Study data included SF12 [12] and Hip disability and Osteoarthritis Outcome Score (HOOS) [13].

Radiographic analysis

AP pelvic views were taken preoperatively, immediately postoperatively and at 1 month, 6 months and 2 years. Images were exported from the McKesson Radiology™ archiving system (McKesson, San Francisco, CA) to the GNU Image Manipulation Program™ (GNOME Foundation, Orinda, CA) and calibrated using the known screw diameter and length. On last-follow-up radiographs, the healthy side was traced, reframed and superimposed on the operated side, with the inter-trochanter line, greater trochanter and femoral cortices as landmarks (Figure 2). Frames were then traced on the superior and medial edges of the femoral head and measurements were made using Mesurim Pro software v 3.4. The horizontal distance between the medial edges of the femoral head on ipsi- and contra-lateral view represented the shortening of the horizontal or abductor lever arm, designated "X". The distance between the superior edges of the femoral head on ipsi- and contra-lateral view represented the vertical shortening, designated "Y" (Figure 3). Cervico-diaphyseal angle was measured between the axis through the femoral shaft and the axis through the center of the femoral head and neck [8,14].

Reduction quality was assessed following Lowell [15]: non-satisfactory if >5° in varus or valgus compared to the contralateral side or >5mm difference in X or Y.

Garden grade and Pauwels angle were assessed on preoperative views. Vertical and horizontal shortening and cervico-diaphyseal angle after reduction were assessed on immediate postoperative views. Horizontal shortening (X) and vertical shortening (Y) were assessed on 2-year views as described above and vector "Z" ($\vec{\mathbf{X}} + \vec{\mathbf{Y}} = \vec{\mathbf{Z}}$), corresponding to femoral head retraction, was calculated. Complications were noted at each time-point.

2.4 Assessment

The main endpoints were survival and complications requiring surgical revision, such as non-union, primary AON or AON secondary to hardware removal. Non-union was defined by non-consolidation on 6-month radiographs, secondary displacement by need for surgical revision, and AON by clinical symptoms and imaging (X-ray, CT, scintigraphy or MRI). An example of progression to AON is shown in figure 4.

Secondary endpoints comprised survival according to reduction criteria (X and Y shortening, varus/valgus), use of a screw washer in internal fixation, patient-related risk factors (smoking, alcohol, corticosteroids, age), trauma kinetics, time to treatment (< / > 6 hours), and functional (HOSS, SF12) and radiological result (X, Y, Z) at ≥2 years.

2.5 Statistics

Analyses used Stata software v15 (StataCorp, College Station, TX). All tests were 2-tailed, with the significance threshold at p< 5%. Quantitative variables were reported as mean±standard deviation (range) and categoric or binary variables as number and percentage. Failure and complications rates, treated as censored data, were estimated on Kaplan-Meier survival analysis, with surgery as starting date and failure/complication as event or else the date of last news. Survival values (for complications) were compared on log-rank test for binary/categoric variables and on a Cox model for continuous variables. A multivariate Cox proportional hazards model was used to analyze complications adjusted on clinically or statistically relevant factors emerging from the univariate analysis. Results were reported as hazard ratios with 95% confidence intervals.
Associations between neck shortening and functional scores were assessed on Spearman correlation coefficients.

3. RESULTS

Mean follow-up was 5.3 ± 3.0 years [range, 2.0-13.6 years]. At 2 years, 23 of the 112 patients (20.5%) had developed complications: 10 osteonecroses (8.9%) and 13 non-unions (11.6%) (figure 5). Mean time to onset was 258.5 ± 219.5 days [21-730]. 27 patients (24.1%) underwent total hip replacement, the others being cases of AON awaiting arthroplasty. There were 14 deaths (12.5%), unrelated to fracture. 48 patients without complications (60.8%) underwent hardware removal for functional difficulty and/or acquired consolidation. Revision rates for complications at 2 years according to Garden grade were: 1/30 (3.3%) for Garden 1, 4/21 (19.0%) for Garden 2, 11/38 (28.9%) for Garden 3 and 7/23 (30.4%) for Garden 4.

3.1 Risk factors

Analysis of survival according to risk factors found no significant differences at 2 years: Hazard Ratio (HR) 1.15 [95%CI: 0.51 – 2.61], p 0.73 for gender; HR = 1.87 [95%CI: 0.63 – 5.57], p = 0.27 for smoking; HR = 0.3 [95%CI: 0.04 – 2.23], p = 0.15 for corticosteroids; HR = 1.35 [95%CI: 0.44 – 4.09], p = 0.78 for alcohol; and HR = 0.45 [95%CI: 0.15 – 1.31], p = 0.13 for kinetics. Three age-groups were distinguished: < 50, 50-59 and > 60 years; there were no differences in survival (p = 0.86).

Distinguishing stable (Garden ≤ 2) and unstable fracture (Garden ≥ 3), the latter showed significantly greater failure: HR = 2.77 [95%CI: 1.09 – 7.02], p = 0.025 (figure 6). No associations were found for Pauwels grade (p= 0.4722).

3.2 Treatment and fixation

Analysis of survival according to surgical treatment and fixation results found that use of a screw washer (89 cases; 79.5%) did not affect survival: HR = 0.57 [95%CI: 0.23 – 1.38], p = 0.23. Immediate postoperative radiographs showed a mean cervico-diaphyseal angle of 131.7 ± 4.4° [119-147°], with 76 valgus reductions, including 45 with ≥ 5° difference, and 28 varus reductions, including 7 with ≥5° difference. Four patients had >5mm reduction deficit in X, 58 had > 5 mm X shortening, 23 had >5mm reduction deficit in Y, and 20 had > 5 mm Y shortening. Mean X shortening was 4.9 ± 6.0 mm [-19.2 to 13,8] and mean Y shortening -0.1 ± 5.3 mm [-12.6 to 12,6]. Table 1 presents data for reduction quality.

There was no significant difference according to time to treatment (≤ 6 hours): HR = 1.08 [95%CI: 0.46 – 2.54], p = 0.86, if cut-off exceeded.

There was no significant difference according to reduction in valgus (HR = 0.39 [95%CI: 0.13 – 1.16]) or varus (HR = 1.13 [95%CI: 0.38 – 3.38]) (p = 0.0515), or according to Y shortening (p = 0.25). There was, on the other hand, a significant difference according to X lengthening (p < 0.001), with HR = 9.45 [95%CI: 2.16 – 41.44] for values in the quartile of least shortening (<1.62 mm) or lengthening (figure 7). The quartiles were >8.11 mm, 8.11-5.22 mm, 5.21-1.63 mm, and <1.62 (including lengthening (Table 1).

The various factors are shown in Table 2.

3.3 2-year clinical and radiological assessment

Clinical results in the 45 patients who could be seen in consultation (57%) were satisfactory for 31 (68.9%), acceptable for 10 (22.2%) and disappointing for 4 (8.9%). HOOS, filled out by 52 patients, showed a mean pain score of 82.6 ± 18.4 [25-100], symptoms score of 81.2 ± 17.6 [25-100], sports score of 78.5 ± 21.0 [18.75-100], activities of daily living score of 87.9 ± 12.6 [48.5-100] and quality of life score of 80.3 ± 23.3 [25-100]. Mean SF-12 scores were 45.8 ± 11.1 [13–61] for the physical component, and 52.1 ± 12.5 [23–71] for the mental component, with global score of 49.1 ± 10.3 [16–71].

Two-year radiographs showed a mean Z shortening of 12.3 ± 4.8 mm [-0.7 to 26.2], X shortening of 8.5 ± 5.0 mm [-6.8 to 23,9] and Y shortening of 6.4 ± 6.1 mm [-6.3 to 25.3], with 24 patients (27%) showing 5-10 mm shortening and 57 (67%) >10 mm. Z shortening showed a non-significant negative correlation with the SF12 physical component($r = -0.22$; $p = 0.12$), and a significant negative correlation with the mental component ($r = -0.28$; $p = 0.046$). HOOS pain score showed a significant negative correlation with Z ($r = -0.38$; $p = 0.005$), quality of life a non-significant negative correlation ($r = -0.20$; $p = 0.16$) and sport a significant negative correlation ($r = -0.28$; $p = 0.039$).

DISCUSSION

The present complications rate was slightly different from that reported by Damany et al. [7] in a meta-analysis of 564 patients, or Duckworth et al.'s study of risk factors [16], with an overall complications rate of 31.9%, compared to 29.5% in the present study, comprising 7.4-8.9% non-union, compared to 11.6%, and 23-32% AON, compared to 17.9% . This lower rate may have been due to stricter selection for internal fixation: patients with low life-expectancy or who were non-cooperative were managed more by arthroplasty if they were close to or over 60 years of age. This selection has important socioeconomic implications, given the forecast strong increase in incidence of these fractures [17], notably as screw fixation is associated with high rates of complications in frail and elderly subjects [18]. Moreover, onset can be as much as 10 years post-trauma, which needs to be borne in mind for follow-up.

Analysis of secondary endpoints found a lower complications rate in stable fracture (Garden 1 or 2), as reported elsewhere [8,19]. Findings regarding time to treatment are controversial; Damany et al., in their meta-analysis [7], like in the present study, found no link between complications and time to treatment (cut-off, 12 hours), whereas Duckworth et al. [16] found a 24-hour cut-off. Analysis of survival according to patient-related risk factors and lifestyle revealed no impact on AON or non-union in the present study, while other studies reported smoking as a risk factor for complications, and also alcohol abuse, age and comorbidities such as kidney or respiratory failure [19]. Some of the present findings may have been influenced by the retrospective design and preselection aimed at reducing the risk of complications.

No link emerged between type of trauma and onset of complications, but trauma mechanisms in this age-group are often low-energy, which may have biased the analysis, as only 29.9% of fractures involved high-energy trauma; similar findings were reported by Al Ani et al. [20]. A negative impact of poor initial reduction quality was reported by Sprague et al. [19] to be associated with increased risk of surgical revision. Wang et al. also reported a higher rate of complications, and notably femoral head AON, in case of unsatisfactory reduction with residual displacement [21].

Some studies of screw fixation of femoral neck fracture and the resulting shortening did not include functional assessment; one that did found a negative correlation at 6 months regarding physical function [22], while Weil et al. [14] found a negative correlation between SF-12 physical component and shortening (p=0.048), as in the present study, although not all correlations were significant and none were very strong.

In the present series, shortening was almost systematic at 2 years' follow-up, with 24 patients (28.9%) showing 5-10 mm shortening and 57 (68.9%) with >10 mm. this was surprising in the light of the literature: Stockton et al. reported 54% of patients with >5 mm shortening (22% 5-10 mm and 32% >10 mm) [9], while Zlowodzki et al. [22], in an older population, reported 36% of patients with 5-10 mm shortening and 30% with >10 mm. Weil et al. [14] reported a 51% rate of >5 mm shortening, including 22% >10 mm. In these studies, assessment was at 6 weeks and 6 months; the differences may be due to long-term progression, with shortening continuing after 6 months and progressive physical impairment over time. Regarding initial reduction, although there were no significant associations with varus or valgus reduction, there did seem to be fewer complications with valgus: HR = 0.49 even if p = 0.08. This possibility is borne out by Muller [23], for whom femoral neck valgization osteotomy is indicated for femoral head AON and post-traumatic non-union. Moreover, valgization shortens X, which appears to have a protective effect. Regarding fixation material, screw washers seem unnecessary in this young population; regarding screws, Weil et al. [14] demonstrated that fully threaded screws limited neck shortening at 6 months. Other interesting possibilities include computer-assisted navigation [24], which sems to provide good long-term results, especially regarding neck shortening.

The present study had certain limitations. 1) Radiologic analyses were made by a single observer. 2) Moreover, surgery involved a number of operators with variable experience, directly impacting reduction quality. 3) The study protocol diverged a little from the literature: non-weight-bearing is generally for 6 weeks [25] for 6-month shortening no greater than in the present series (6.23 ± 4.5 mm for Weil, versus 12.3 ± 4.8 mm). This allowed earlier return to activity without, apparently, increasing complications; however, follow-up was only 6 months. 4) The reduction and displacement measurements could have been more precise if CT had been used. The present vectoral measurements were probably biased: we attempted lateral analysis to assess posterior displacement, but the quality of lateral images did not allow this analysis; our reduction cut-off of 5° is open to criticism, as Garden 1 fractures are classically not reduced but fixed in-situ and some fractures may thus have been considered poorly reduced, although this was deliberate on our part.

4. CONCLUSION

The present study showed relatively low rates of complications and of arthroplasty; The literature reports high complications rates, without consensus as to optimal management. It would be useful to focus on systematic valgization with moderate X shortening as a means of reducing complications and improving functional outcome. Indications seem broad, mainly concerning the patient's general health status and wishes rather than age or smoking/alcohol status, especially if screwing is seen as a means of avoiding or delaying hip replacement. Regarding time to treatment, internal fixation seems indicated even when with delay greater than 6 hours.

Disclosure of interest:

SB is a consultant for Zimmer. The other authors have no conflicting interests to disclose.

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Author contributions:

RE: study set-up, data collection, article writing and re-editing
GF: study set-up, data collection, article writing
GV: re-editing
AM: statistics
SB and SD: study set-up and re-editing

Table 1: Degrees of shortening

	Reduction defect	Shortening		
	≥ 5 mm	< 5 mm	5-10 mm	≥ 10 mm
X	4(3.6%)	50(44,6%)	37(33%)	21(18.8%)
Y	23(20.5%)	68(60,7%)	19(17%)	2(1,8%)
	≥ 5°			
Valgus	45(40.2%)			
Varus	7(6.3%)			

Table 2: Risk factors

		Hazard Ratio	p-value	95% CI
Variables at 2 years				
Age			0.86	
	50-59 years	0.81		0.31 ; 2.09
	> 60 years	0.76		0.26 ; 2.19
Female gender		1.15	0.73	0.51 ; 2.61
Displaced fracture (Garden 3 or 4)		**2.77**	**0.025***	1.09 ; 7.02
Pauwels angle			0.4722	
	Pauwels 2	1.49		0.33 ; 6.8
	Pauwels 3	2.09		0.46 ; 9.42
Smoking		1.87	0.27	0.63 ; 5.57
Alcohol		1.35	0.78	0.44 ; 4.09
Corticosteroids		0.3	0.15	0.04 ; 2.23
High-energy trauma		0.45	0.11	0.15 ; 1.31
Time to treatment > 6h		1.08	0.86	0.46 ; 2.54
Use of screw washer		0.57	0.23	0.23 ; 1.38
X shortening			**p < 0.001***	
	8.11-5.22	0.48		0.04 ; 5.31
	5.21-1.63	2.71		0.53 ; 13.99
	< 1.62 (and lengthening)	9.45		2.16 ; 41.43
Y **shortening**			0.25	
	4.1-0	2.1		0.56; 7.93
	Lengthening: 0.1-3.51	1.45		0.29 ; 7.2
	Lengthening > 3.6	3.31		0.9 ; 12.22
Reduction angle			0.0515	
	Valgus	0.39		0.13 ; 1.16
	Varus	1.13		0.38 ; 3.38

Figure 1 : Flowchart

Figure 2: Creation of tracing

Figure 3: Measurement of X and Y

Figure 4: Example of screw fixation progressing toward aseptic osteonecrosis of the hip

Figure 5: Flowchart of 2-year results

Figure 6: 2-year survival according to fracture displacement

% complications

Stable fracture

Unstable fracture

Time to onset

Figure 7: 2-year survival according to X shortening. (Q : quartile)

% complications

X shortening

Time to onset

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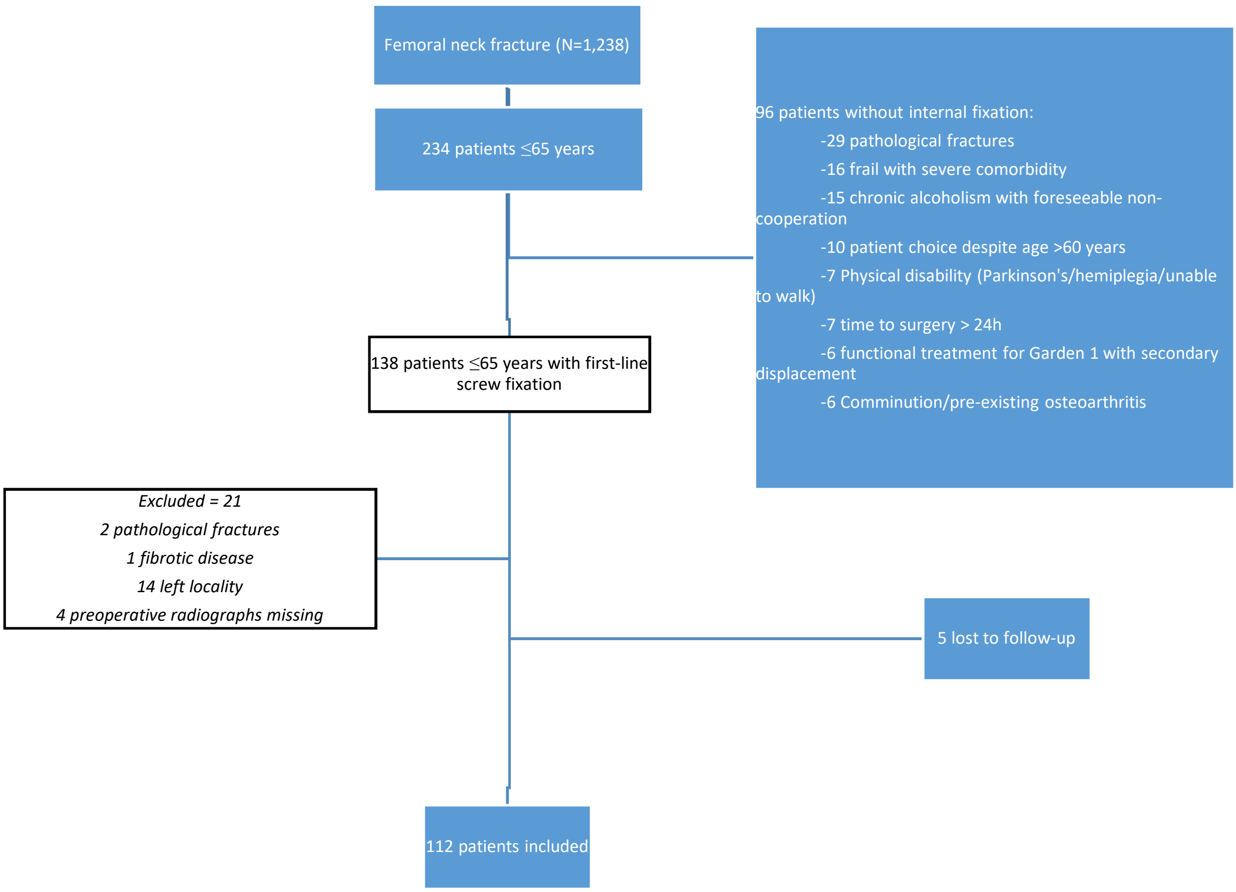

Femoral neck fracture (N=1,238)
234 patients ≤65 years
96 patients without internal fixation:
-29 pathological fractures
-16 frail with severe comorbidity
-15 chronic alcoholism with foreseeable non-cooperation
-10 patient choice despite age >60 years
-7 Physical disability (Parkinson's/hemiplegia/unable to walk)
-7 time to surgery > 24h
-6 functional treatment for Garden 1 with secondary displacement
-6 Comminution/pre-existing osteoarthritis
138 patients ≤65 years with first-line screw fixation
Excluded = 21
2 pathological fractures
1 fibrotic disease
14 left locality
4 preoperative radiographs missing
5 lost to follow-up
112 patients included

Figure 1 :

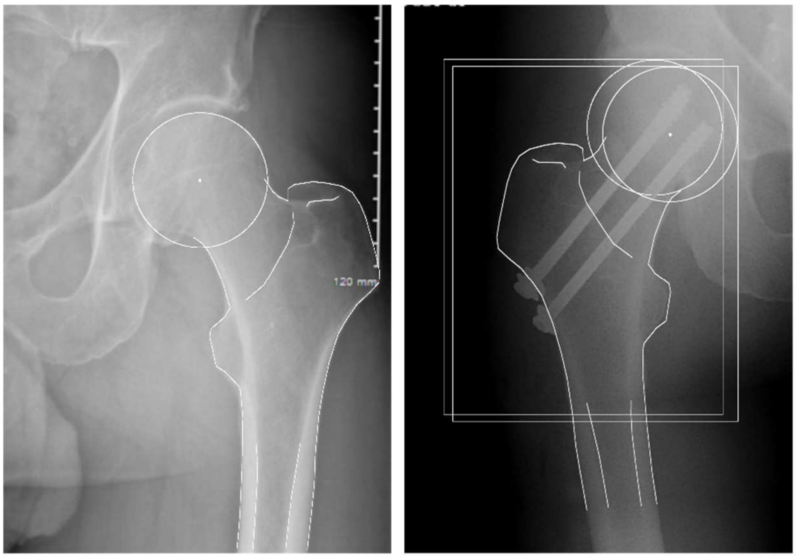


Figure 2:

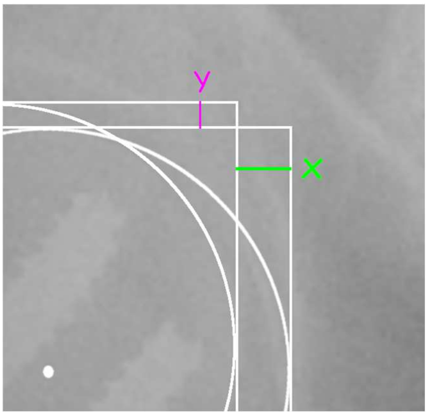


Figure 3:

Figure 4 :

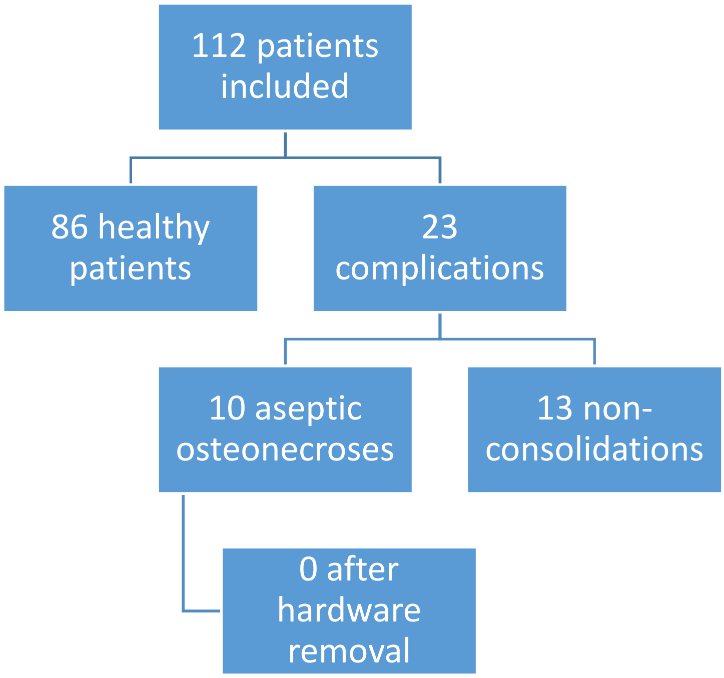
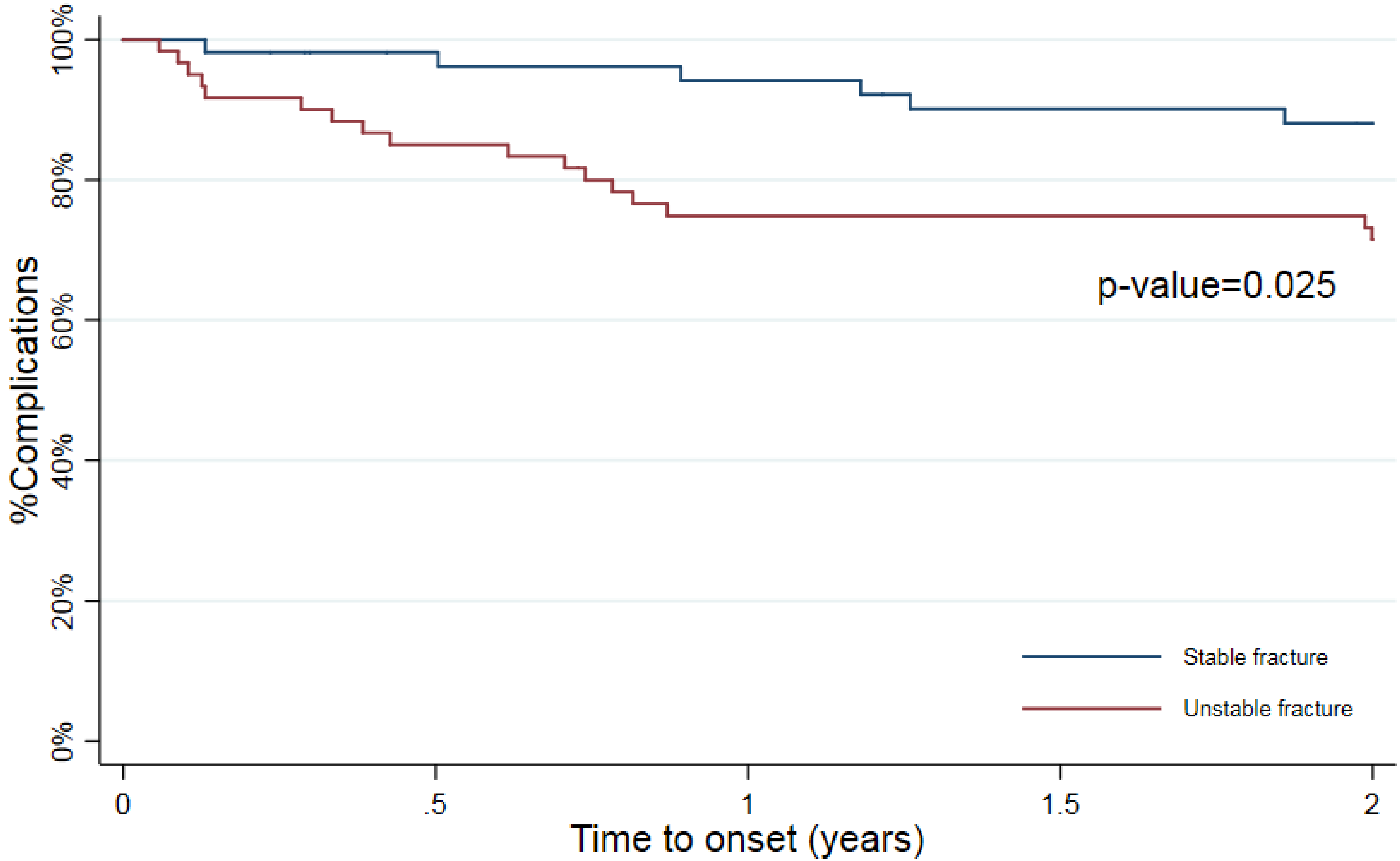
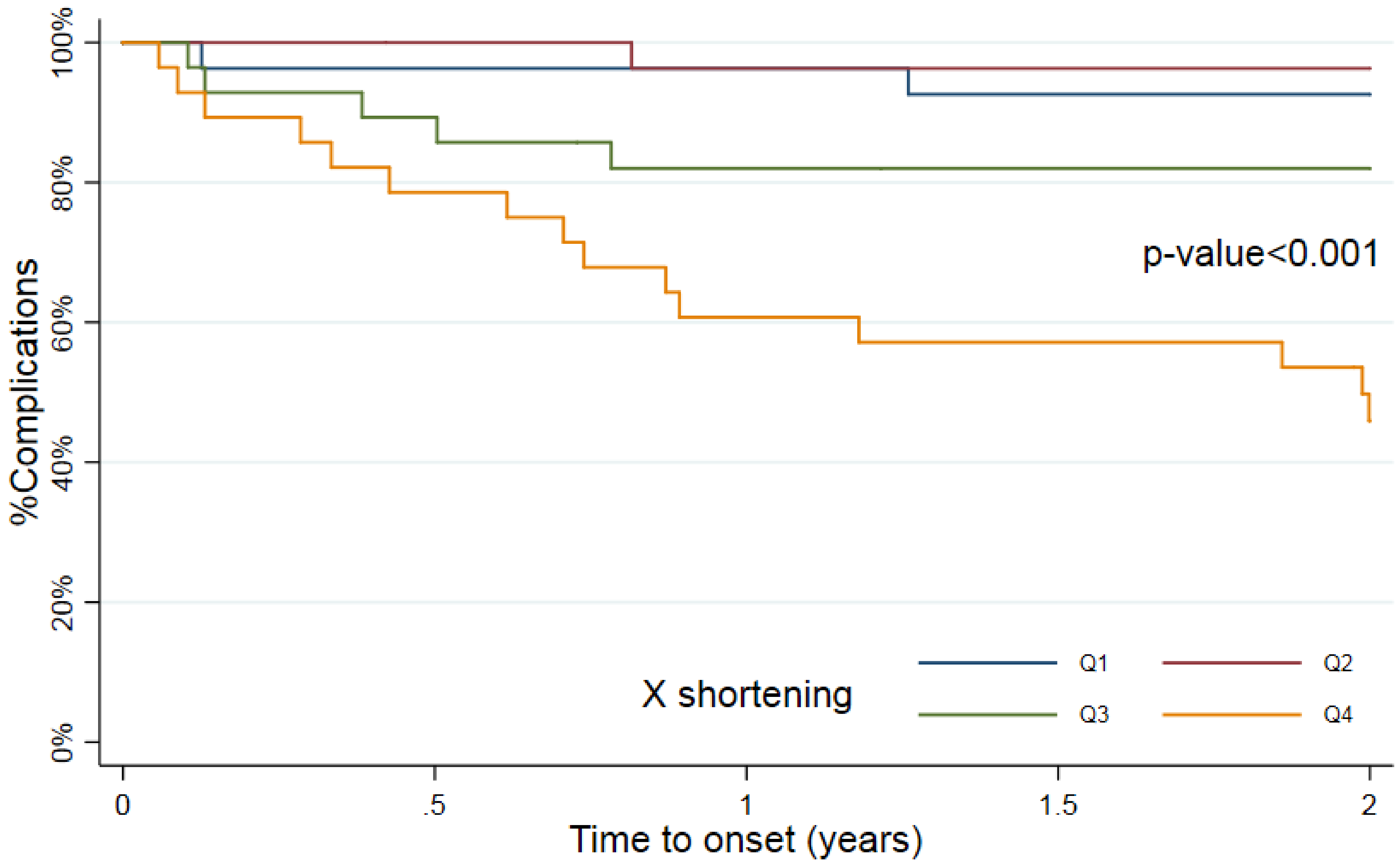

112 patients included
86 healthy patients
23 complications
10 aseptic osteonecroses
13 non-consolidations
0 after hardware removal

Figure 5:



100%
80%
60%
40%
20%
0%
%Complications
p-value=0.025
Stable fracture
Unstable fracture
0
.5
1
1.5
2
Time to onset (years)



100%
80%
60%
40%
20%
0%
%Complications
p-value<0.001
X shortening
Q1
Q2
Q3
Q4
0
.5
1
1.5
2
Time to onset (years)