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Femoral neck nonunion: new classification used in total hip arthroplasty in elderly patients

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Annotation

Introduction The risk of the femoral neck fracture nonunion is 48 % with avascular necrosis of the femoral head being reported in 42 % of cases. There are many classifications of acute intra-articular fractures of the proximal femur and there are no grading systems for femoral neck nonunions that would allow prediction of outcomes of total hip arthroplasty (THA). **The objective** was to evaluate mid-term results of THA in patients with femoral neck nonunion and develop a new classification of nonunions. **Material and methods** A prospective cohort single-center comparative study included 78 elderly patients with atrophic femoral neck nonunions treated with primary THA. The mean follow-up period was 24.2 months. Three prospective groups were identified. Separation criteria included shortening of the lower limb and femoral offset, changes in the Barnett-Nordin index, the Hounsfield bone density index, the presence of metal constructs and bone defects. Groups A and B were divided into 2 subgroups depending on the presence/absence of fixation metal constructs for a femoral neck fracture. Group C was divided into 2 subgroups: type C_1, acetabular defect and type C_2, proximal femur defect. **Results** Mean operating time was 81.1 minutes in group A, 102.9 minutes in group B and 145.2 minutes in group C. The minimum blood loss was recorded in group A measuring on average 429.25 mL in both subgroups. The maximum blood loss was seen in patients of groups B and C measuring 606.62 mL and 631.5 mL. Overall revision rate was 7.7 %. **Conclusion** A classification for femoral neck nonunions was developed suggesting grading patients into 3 types: type A, type B and type C which were further divided into 2 subtypes. The grading system was based on lower limb shortening and femoral offset, severity of osteoporosis, presence of metal constructs and acetabulum or proximal femur bone defect which prognostically affected the outcome of THA.

Keywords: nonunion, femoral neck, classification, arthroplasty, hip joint

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INTRODUCTION

Avascular necrosis of the femoral head and atrophic femoral neck fracture nonunion are most severe orthopaedic complications of intracapsular fractures of the proximal femur. Elderly patients are at risk [1, 2, 3]. The frequency of femoral neck fractures is steadily increasing every year which leads to an increase in the need for surgical treatment of fractures of this localization and associated complication rate [4]. There were 400,000 hip fractures registered annually with the Swedish Fracture Register (SFR) [5]. The mortality rates after hip fractures are reported to be as high as 80 % during the first year of injury treated conservatively [6, 7]. If the patient "survived" the first year after an intracapsular fracture of the hip, the risk of a nonunion reaches 48 % at this localization, and avascular necrosis of the femoral head is 42 % [8].

Major complications of surgical treatment of femoral neck fracture nonunion include a decrease in the quality of bone tissue as a result of progressing systemic and local osteoporosis due to the lack of a full weight-bearing, shortening of the lower limb and substantial scars over the proximal femur and functional insufficiency of the gluteal muscles [9, 10]. These local changes in the hip anatomy can lead to such complications as intraoperative bleeding (up to 8.6 %), peri-implant fractures (up to 3.5 %), infections (6.4 %) [3]. Total hip arthroplasty (THA) for false joints of the femoral neck in elderly patients is the only effective surgical intervention that allows quick recovery of physical activity to pre-fracture level. However, a high rate of orthopaedic and general somatic perioperative complications, postoperative mortality rate indicate the need for careful preoperative preparation, planning, choice of the type and variant of implant fixation, friction pairs and a postoperative rehabilitation program.

There is a need to classify femoral neck fracture nonunions to provide an objective algorithmization of THA and evaluate results of surgical treatment. There are many classifications of acute intracapsular fractures of the proximal femur considering treatment prognosis. However, there are no classifications of the femoral neck fracture nonunions that would allow predicting outcomes of arthroplasty in elderly patients. The objective was to evaluate results of THA in elderly patients with femoral neck nonunion and develop a new classification of nonunions at this localization.

MATERIAL AND METHODS

A prospective cohort single-center comparative study included 78 elderly patients with atrophic femoral neck nonunions treated with primary THA between 2015 and 2020. The mean follow-up period was 24.2 ± 2.9 months. General characteristics of the patients are presented in Table 1. The average age of the patients was 74.05 ± 7.09 years, the average age of hip fracture was 9.21 ± 2.14 months. The ratio of men and women was 1:1.7. Statistical significance in the frequency of injuries to the right and left lower limbs was not identified.

Research groups were identified using the following parameters: mineral density of cancellous bone (Hounsfield index (HU) measured with multislice computed tomography of the hip joints), Barnett-Nordin cortical index using standard radiographs, the presence or absence of previously installed metal fixators, the amount of shortening lower limb and hip offset, presence or absence of acetabular bone defects or proximal femur defects. Inclusion criteria included atrophic femoral neck nonunion, the timing of the femoral neck of at least 8 months. The exclusion criteria included the size of the bone defect 2C and higher graded with Papovsky classification; infectious process at the hip area; concomitant diseases at decompensation stage in the preoperative period.

Table 1

Main characteristics of patients included in the study

		Group A (n = 27)	Group B (n = 24)	Group C (n = 21)
Age, Me* (min/max)		76 (61; 86)	77 (62; 85)	73 (56; 83)
Timing of fracture, Me (min/max)		10 (6; 13)	9 (5; 12)	11 (8; 16)
Sex	male	9	13	4
	female	18	11	16
Side of involvement	right	15	11	8
	left	12	13	13

*Me, median.

Based on the analysis of modern Russian and foreign literature, the results of our own previous studies on THA in elderly patients with atrophic femoral neck nonunions the authors identified 3 prospective groups of patients. The reported group differentiating factors that would affect the results of surgical treatment included lower limb shortening and femoral offset, changes in the Barnett-Nordin index, the Hounsfield bone density index (HU), the presence of metal constructs and acetabular bone defects or proximal femur defects. Group A included 27 (37.5 %) patients, group B, 24 (33.4 %) patients and group C, 21 (29.1 %) patients. Radiological parameters of the patients of the three groups are shown in Tables 2 and 3. The patients were grouped with the increased severity of osteoporosis and bone defects. Group A included patients with shortening of the lower limb and femoral offset up to 2 cm, with no signs of local and systemic osteoporosis (Barnet-Nordin index over 0.4 units, HU over 120 units) and with no bone defects. Digital plain radiographs of the pelvis, long standings films and TraumaCad software (ver. 2.5) were used to measure shortening of the limb and offset with the weight borne by the healthy limb. Groups B and C included patients with greater shortening of the lower limb, offset of the femur and bone defects. A "piston test" was performed preoperatively using the method developed by Efimov D.N., 2012 [4]. No case required the Ilizarov external fixation to bring the femur down. Groups of patients were divided into subgroups for a more objective assessment of the results of THA. Two subgroups were identified in groups A and B depending on the presence or absence of metal constructs in the proximal femur to fix a femoral neck fracture. Two subgroups were identified in group C including C_1 type diagnosed in 10 patients with acetabular defects and C_2 type detected in 11 patients with proximal femur defects.

Table 1

Radiological characteristics of the Hounsfield and Barnett-Nordin index in patients of the study groups

Parameter	Group A	Group B	Group C
Preoperative cortical index			
Mean ± SD*	0.6 ± 0.17	0.2 ± 0.09	0.3 ± 0.11
P-value	**P_{A-B} = 0.01; P_{A-C} = 0.01; P_{B-C} = 0.38**		
Min-max	0.2–0.9	0.1–0.4	0.1–0.4
Q1; Q3	0.4; 0.65	0.2; 0.4	0.1; 0.4
Preoperative HU, units			
Mean ± SD	121.9 ± 25.1	68.1 ± 8.5	64.7 ± 9.1
P-value	**P_{A-B} = 0.01; P_{A-C} = 0.01; P_{B-C} = 0.78**		
Min-max	65–171	53–82	54–81
Q1; Q3	104; 140	62; 73	59; 81

*SD, standard deviation

Table 3

Radiological characteristics of lower limb shortening and femoral offset in patients of the study groups

	Femoral shortening, mm	Femoral offset, mm
Type A_1	1.11 ± 0.4	11.64 ± 2.7
Type A_2	1.09 ± 0.3	10.69 ± 3.1
Type B_1	2.53 ± 0.2	24.46 ± 7.7
Type B_2	1.29 ± 0.4	12.91 ± 2.5
Type C_1	1.18 ± 0.4	16.31 ± 3.5
Type C_2	2.31 ± 0.38	24.11 ± 3.1
P-value	P < 0.01	

Note: $P_{B1-A1} < 0.01$; $P_{B1-A2} < 0.01$; $P_{B1-B2} < 0.01$; $P_{B1-C1} < 0.01$; $P_{C2-A1} < 0.01$; $P_{C2-A2} < 0.01$; $P_{C2-B2} < 0.01$; $P_{C2-C1} < 0.01$.

All patients were operated on by the same experienced surgical team with the Harding approach in the lateral position using combined spinal-epidural anesthesia. Standard rehabilitation was performed postoperatively with gradual weight-bearing on the operated lower limb for 6 weeks and use of oral anticoagulants to prevent thromboembolic complications. Second-generation cephalosporins were used as antibacterial prophylaxis. Standard cemented and uncemented THA was used for patients of group A depending on preoperative planning. Dual mobility cemented acetabular components and standard cemented femoral components were used for patients of group B due to severe local osteoporosis. Acetabular components normally intended for revision arthroplasty (MultiHoled cups, metal augments) were used for patients of subgroup C_1 with the acetabular bone defect repaired with auto- or allograft. Femoral components of metaphyseal or diaphyseal fixation (Wagner conical or revision stems, Alloclassic standard or revision stems) or polished stems with impaction bone grafting were used for subgroup C_2. Intraoperative blood loss, operating time, severity of pain on a 10-point VAS scale, functional parameters measured with a 48-point Oxford Hip Score (OHS), the rate and nature of orthopaedic complications were evaluated.

Statistical processing of the data

The normality of the distribution of quantitative parameters was identified with the Shapiro-Wilk test (modified by J.P. Royston). The Kruskal-Wallis test was used to assess abnormally distributed samples with the Bonferroni correction, with a posteriori pairwise comparison employing the Mann-Whitney test, the critical significance level was adopted at 0.017. If the distribution was not normal, the median, 25th and 75th percentiles were indicated. The significance of differences in quantitative parameters of the operating time, the cortical Barnett-Nordin index, HU and the blood loss were assessed using one-way analysis of variance with the ANOVA module with resultant Fisher criterion calculated. There were no significant differences between the average values with the value being less than critical. With a statistical difference detected, an additional analysis was performed by pairwise comparison of the populations using Tukey's post hoc test. Hypothesis was tested for related samples using paired Student's test for normal samples and Wilcoxon for the rest. Fisher's exact test was used for small samples for statistical analysis of qualitative parameters of complications and revision intervention rates. The IBM SPSS ver.20 program was used for statistical processing of the data.

RESULTS

The results of THA evaluated in elderly patients with atrophic femoral neck nonunions showed the mean operating time of 81.1 ± 14.2 minutes in 27 patients of group A, 102.9 ± 16.5 minutes in 24 patients of group B and 145.2 ± 19.4 min in 21 patients of group C (Fig. 1).

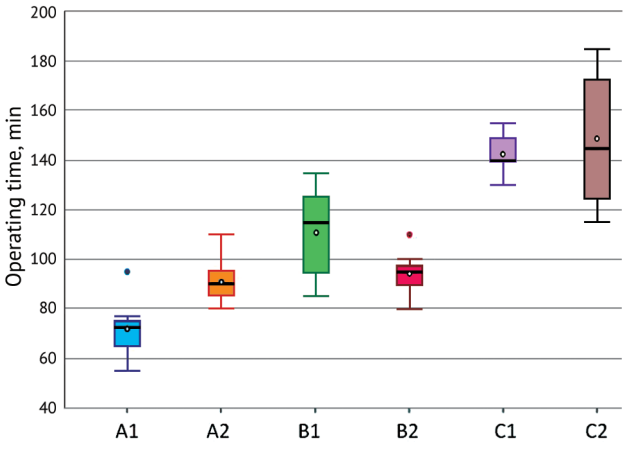

Fig. 1 Operating time measured in the study groups

The parameters were associated with the need for simultaneous removal of metal constructs placed at the proximal femur in groups B and C, additional soft tissue releases in a pronounced lower limb shortening and femoral offset in subgroup B1, and the use of bone grafting to compensate for acetabular and proximal femur defects in group C. There was a statistically significant difference in the operating time between patients of subgroups B_1, C_1 and C_2 (P = 0.00003). The operating time was dependent on the presence of a metal construct, the severity of the lower limb shortening and femoral offset.

The mean intraoperative blood loss of the 6 subgroups is shown in Figure 2. The minimum blood loss was observed in patients of group A measuring the average of 429.25 ± 23.9 mL in both subgroups. The maximum blood loss was seen in groups B and C measuring 606.62 ± 55.4 mL and 631.5 ± 59.5 mL, respectively. A statistically significant difference was observed in the volume of blood loss in patients of group A and groups B and C.

Midterm results of THA were rated as good and satisfactory in 90.2 % of cases in the groups and subgroups. VAS score improved by an average of 89.5 % among patients of all groups and the OHS score measured an average of 36.05 points by the first year of THA (Fig. 3).

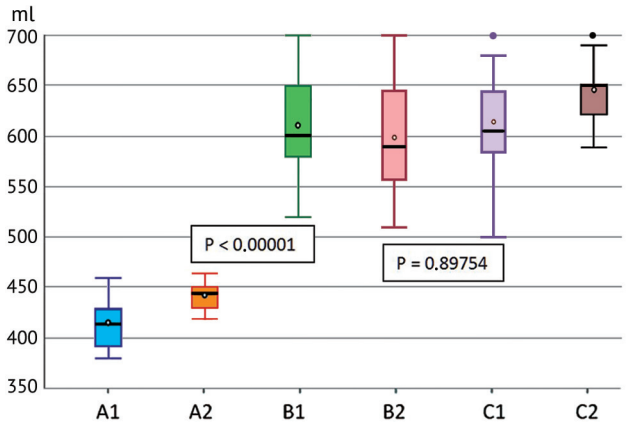

Fig. 2 Intraoperative blood loss in patients of the study groups

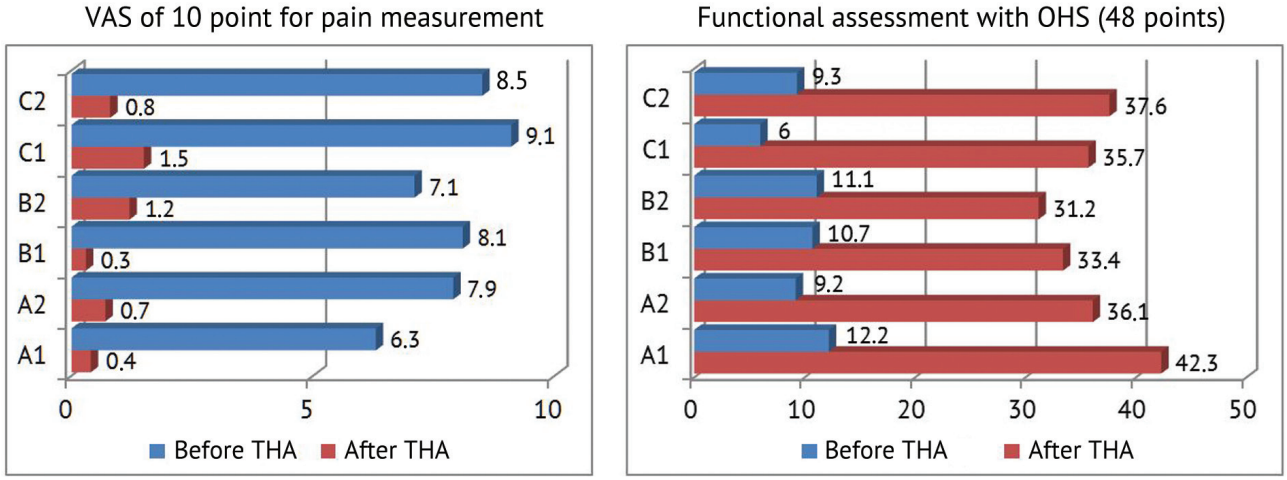

Fig 3 Graphic representation of the results of THA in patients with atrophic femoral neck nonunions in the study groups

The overall rate of revision interventions was 7.7 % (n = 6), and the overall complication rate in all groups was 8.9 %, which is a comparable result of THA patients reported. A greater complication rate was noted in group C (14.2 %) including 2 infectious complications that required a two-stage revision arthroplasty. Infectious complications occurred only in patients with metal constructs placed earlier. The greatest number of implant dislocations was observed in 2 (3.7 %) cases of group A who underwent standard primary THA (Table 4).

Table 4

Complication and revision surgery rate in the studied groups

	Complications, n (%)	Revision, n (%)
A_1 (n = 14), %	1 (7.14) dislocation	1 (3.7)
A_2 (n = 13), %	1 (7.69) dislocation	
B_1 (n = 13), %	1 (7.69) dislocation	2 (8.3)
B_2 (n = 11), %	1 (9.09) infection	
C_1 (n = 10), %	1 (10) infection	3 (14.2)
C_2 (n = 11), %	2 (18.8) aseptic loosening, infection	

Based on the results of the study the authors developed a classification of femoral neck fracture nonunions in elderly patients that graded the pathology in 3 types: type A, type B and type C (Fig. 4). Patients type A had no clinically significant shortening of the lower limb (no more than 2 cm) and femoral offset (from 1.5 to 2 cm), no local osteoporosis (radiographically the Barnett-Nordin index being more than 0.4; HU (Hounsfield index) measuring more than 120 units in the acetabulum on MSCT). Type A2 was additionally identified for patients who had had a metal construct to fix the femoral neck fracture. Patients type B were classified as those with a significant shortening of the lower limb and femoral offset, and the authors offered implantation of dual mobility cement acetabular components to reduce the incidence of implant dislocations in the postoperative period. There was a type B_2 additionally identified to include patients who had had a metal construct to fix the proximal femur fracture. The subtypes (A_2, B_2) were associated with greater operating time, intraoperative blood loss with a need for antibiotic prophylaxis up to 5 days. The

authors would recommend implantation of cemented femoral components due to severe local osteoporosis for patients type B. Patients type C nonunions had bone defects in addition to the presence of metal constructs according to the classification offered. Subtype C_1 was characterized by an acetabular defect and subtype C_2 featured a bone defect in the proximal femur. Notably, bone defects of the acetabulum and the proximal femur could be graded as type 2B defect according to the W. Paprosky classification. The presence or absence of a metal construct at the site of the proximal femur, bone defects in the acetabulum or proximal femur, the magnitude of lower limb shortening and femoral offset, the severity of local osteoporosis were criteria used to predict outcomes of THA in elderly patients with femoral neck nonunions.

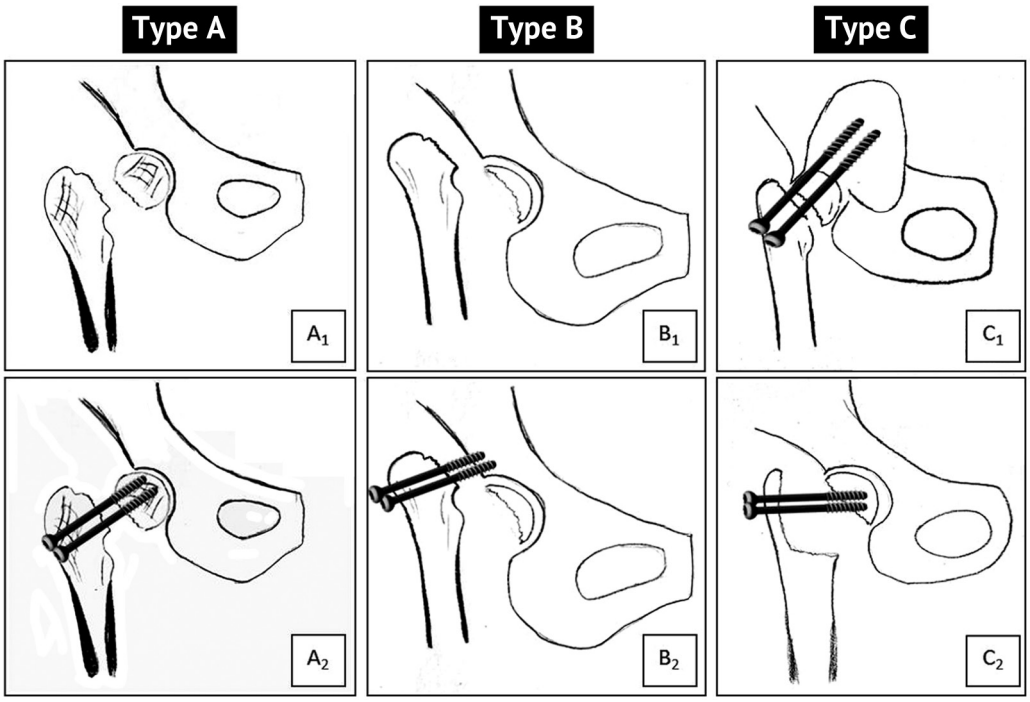

Fig. 4 Classification of femoral neck nonunions (described in the text)

DISCUSSION

Treatment of femoral neck nonunions is an extremely complex and socially significant problem, for elderly patients, in particular. The timing from primary fixation of an intracapsular fracture of the proximal femur to the migration of the metal construct is reported to range between 5.5 and 31.2 months, up to 37 months between internal fixation and THA [11]. Apart from inadequate treatment strategy, the reasons for the femoral neck nonunion can be divided into 2 categories: fracture related pattern and the patient related factor. Conservative or surgical treament of a fracture that is obviously unfavorable in terms of prognosis (AO type B_2, Garden stage III–IV, Pauwels type III) can result in poor outcome. S.E. Asnis et al. reported nonunions developed in 20 % of Garden Stage II and III femoral neck fractures and more than 30 % with Garden Stage IV fractures [11]. Patient related factors include the quality of bone tissue, physical activity and comorbidity. Meta-analysis performed by D.F. Xu et al. indicated nonunions developed in 7.4 % of patients with osteoporotic fractures of the femoral neck with the rate increased to 30 % in conservatively treated patients [12]. Dyscirculatory encephalopathy and senile dementia were found to be severe comorbid risk factors for femoral neck nonunion. B.J. Park et al. reported about 10.5 % of femoral neck nonunions developed in patients with senile dementia who underwent PFN-A (proximal femoral nail antirotation), one of the most stable types of osteosynthesis for these fractures [13].

THA is the most effective technique and can be a single surgical option for femoral neck nonunions in the elderly [12, 14]. THA is also associated with a higher complication rate in the cases. Bleeding, periprosthetic fractures, dislocations and infections are most severe orthopaedic complications reported [15]. Aseptic loosening of implant components is an adverse event associated with primary THA in femoral neck nonunions. T.M. Mabry et al. reported 93 % survival

of total cemented arthroplasty at 10 years and only 76 % survival at 12 years [16]. Migration of hardware components, bone defects in the acetabulum or proximal femur are serious problems of THA in patients who had undergone osteosynthesis for a femoral neck fracture. D.J. Stockton et al. reported a large population cohort of 796 patients with hip fractures treated surgically with focus on conversion to arthroplasty [17]. The authors reported THA in 29% of cases, unipolar arthroplasty in 3 % of cases, re-osteosynthesis in 10 % of cases; 3 % of arthroplasty cases required bone grafting and another 1 % required corrective osteotomy of the femur. These data indicate to the difficulty of choosing appropriate surgical intervention for femoral neck fracture nonunion and the metal construct to be implanted. The use of revision implants, constrained implants and dual mobility systems can be practical considering the risks of primary THA in the elderly with femoral neck fracture nonunion and potential complications. S. Tarasevičius et al. reported no implant dislocations in 105 patients treated with dual articulation systems at one year, compared to 10.4 % of dislocations with use of standard acetabular components [18].

The use of dual mobility systems in group A was effective but not justified with dislocations being not statistically significant. Recent comparative studies of standard components and those with dual mobility indicated no benefits for 3 postoperative months [19]. No standard components were used in group B since a higher rate of dislocations were reported in severe osteoporotic cases of femoral neck fracture nonunion [20]. Compared with the use of bipolar cups, dual mobility systems demonstrated a statistically significant difference in the incidence of head dislocations. A.S. Bensen et al. data reported the incidence of dislocations of bipolar cups in 14.6 % in patients with femoral neck fracture nonunion, compared with 4.6 % when using dual mobility systems [21].

CONCLUSION

The authors developed an original classification of femoral neck fracture nonunion for the elderly. Predictively, the presence of a metal construct, a bone defect and a pronounced limb shortening resulted in increased operating time, intraoperative blood loss, the risk of infectious complications and dislocations. Acetabular components of dual mobility cement fixation can be practical for fractures graded types B and C considering greater incidence of implant dislocations in the postoperative period and the severity of local osteoporosis. With the classification offered, the authors could obtain good and satisfactory results of THA in 90.2 % of elderly patients who suffered one of the most complicated orthopaedic pathologies, femoral neck fracture nonunion.

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