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ORIGINAL PAPER

What is the fate of the neck after a collum femoris preserving prosthesis? a nineteen years single center experience

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Abstract
Purpose The aim of our study is to evaluate long-term outcomes from a cohort of patients treated with collum femoris preserving (CFP) stem correlating neck resorption with comorbidities, clinical outcomes, and complications.
Methods One hundred seventy-six patients (194 hips) were retrospectively reviewed with a minimum follow-up (f.u.) of ten years. Demographic and surgical data were collected. Clinical and radiological evaluation was performed at the last follow up. We calculated a neck resorption ratio (NRR) for each patient. Main complications were recorded. A p-value of <0.05 was considered significant.
Results The mean Harris hip score (HHS) was 89.1 ± 5.7. The mean visual analogue scale (VAS) and Oxford hip score (OHS) values were 1.1 ± 1 and 41.3 ± 5.1, respectively. The mean leg length discrepancy was 1.5 mm ± 1.9. The mean NRR was 0.35. We observed six cases of aseptic loosening, two cases of infection, one implant revision for recurrent dislocation, and one stem revision after periprosthetic femoral fracture. The overall survival rate of the stem was 94.8%. Statistically significant associations were found between NRR and steroid therapy/stem malposition. Correlation between aseptic loosening and NRR was also statistically significant. Correlations between NRR and HHS/OHS were −0.34 and −0.28 respectively. Odds ratio for aseptic loosening were: 4.6 if NRR > 0.25; 16.9 if > 0.50 and 24.1 if > 0.75.
Conclusion CFP hip stem provided excellent long-term outcomes. NRR is correlated to steroid therapy and stem malposition. The risk of stem aseptic loosening rises according to NRR increase. Patients with an NRR > 0.5, especially if under steroid therapy or with stem malposition, should be strictly monitored.

Keywords Aseptic loosening · CFP · Neck preservation · Tissue sparing surgery · Total hip arthroplasty · Total hip replacement

Introduction

Total hip arthroplasty (THA) in younger and active patients is increasing nowadays [1, 2]. In such patients, it is often necessary to spare as much tissue as possible by removing only the pathological tissue. This approach reflects adherence to the principles of tissue sparing surgery (TSS) [3, 4]. The aim of hip TSS is to achieve implant integration into the natural joint; not a simple joint substitution [5].

A cornerstone of hip TSS is femoral neck preservation. One of the earliest neck preserving stems was the Pipino's Biodynamic (Howmedica, Mahwah, New Jersey) followed by the Collum Femoris Preserving (CFP) stem (Waldemar LINK GmbH & Co, Hamburg, Germany) [6, 7]. CFP is considered a short stem and requires a subcapital femoral neck osteotomy [8]. Femoral neck preservation leads to several biomechanical and biological advantages such as better hip biomechanics restoration, triplanar stem stability, and neck blood supply maintenance [6, 9, 10]. Despite promising evidence, few data about neck resorption and its consequences on stem stability are available in literature.

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The aim of our study is to evaluate the fate of the neck after THA using CFP hip stem at long-term follow up (f.u.). We consider eventual neck resorption and examine its correlation with relevant comorbidities, demographic data, clinical outcomes, and complications.

Materials and methods

A cohort of 176 patients (194 hips) who underwent cementless total hip replacement with the CFP short stem prosthesis from 1997 to 2006 was investigated in a retrospective observational study. Informed consent was obtained from each individual participant included in the study. Only patients presenting a diagnosis of hip osteoarthritis grade III and IV according to the Kellgren-Lawrence classification were enrolled. Exclusion criteria were severe osteoporosis (defined as a T-score of less than 2.5 standard deviations at dual-energy X-ray absorptiometry with a previous fragility fracture), Crowe III and IV congenital hip dysplasia (CHD), and acute femoral-neck fracture. Demographic characteristics such as current age, sex, age at surgery, bisphosphonate use (> 1 year), body mass index (BMI), smoker status and baseline comorbidities were recorded. Surgical parameters were also collected which included stem curve and size, type of cup, affected side, and pre-operative diagnosis.

The authors set the minimum f.u. at ten years with an f.u. span of nine years (10–19 years). Clinical evaluations using the Harris hip score (HHS) [11], visual analogue scale (VAS), Oxford hip score (OHS), leg length discrepancy (LLD), and thigh pain were performed at the last f.u. According to HHS, results were grouped as being excellent (≥90 points), good (89–80), fair (79–70), and poor (<70). The radiographs were analyzed independently by two experienced orthopedic surgeons (MF and LF). Radiological data such as cup and stem loosening, stem osteolysis according to Gruen zones [12], cortical hypertrophy, heterotopic ossifications (HO) according to Brooker Classification, varus/valgus malposition of the stem (>5°), and stem subsidence were performed. For each patient, an X-ray study (antero-posterior with 15° of internal rotation and frog-leg view) was obtained at the last f.u.

In order to avoid magnification bias, we calculated a neck resorption ratio (NRR) dividing the distance (millimeters) between the medial tip of the collar and the medial apex of the remaining neck by the length (millimeters) of a straight line traced from the medial tip of the collar to the apex of the lesser trochanter (Fig. 1). Complications such as septic or aseptic loosening and time between implant and revision, periprosthetic fractures, further surgery on the operated hip, dislocations, and surgical wound troubles were collected.

Study population

From 1997 to 2006, a total of 228 patients underwent THA with CFP stem in the Clinica Ortopedica of the San Martino Hospital in Genoa. The authors reviewed 176 patients, or 194 hips of which 18 were bilateral. Fifty two patients were lost at f.u., of which 37 died during the f.u. period. The global drop-out rate was 22.8%. Ninety-eight were females and 78 were males. The mean age was 74.7y ± 9.8 and the mean age at surgery was 60.6y ± 9.1. The mean age at final f.u. was 73.7y ± 10. The mean BMI at the last f.u. was 26.7 ± 3.6. The mean f.u. period was 14.2y ± 2.1. Relevant comorbidities are summarized in Table 1.

Operative technique and post-operative care

In all cases, a modified direct lateral Hardinge approach was used [13]. All procedures were performed by an experienced orthopaedic surgeons with the patient in lateral position under general or local regional anesthesia.

The CFP stem is made of Tilastan® [titanium, 6 aluminum, 4 vanadium (Ti-6Al-4VA)]. The proximal two thirds are coated with a calcium phosphate coating (HX®, DOT, Rostock, Germany). To improve osteointegration, the CFP stem has a 70 μm pore size (excluding the short distal portion) applied electrochemically. The stem is designed as a left or right version, with 14° of neck anteversion built in, two anatomic curvatures (126° curve A and 117° curve B) and six stem sizes available. The stem has an elliptical collar that allows proximal femoral bone stock preservation and better loading of the femoral neck.

One surgical drain was used until the second post-operative day. An intravenous antibiotic course was administered until the drainage removal. Patients were mobilized with partial weight bearing (50% of body weight) for the first week followed by a rapid progression to full weight bearing afterward.

Surgical data

Pre-operative diagnosis was osteoarthritis in 193 (84.6%) patients; femoral head osteonecrosis in 15 (6.6%) of which three were lost at f.u.; post-traumatic avascular necrosis in 12 (5.3%); CHD in seven (3.1%); and one patient with slipped capital femoral epiphysis (0.4%). Of the stems, 189 were coupled with TOP (Trabeculae Oriented Pattern, Waldemar LINK GmbH & Co, Hamburg, Germany) acetabular system; three with Plasmacup (Aesculap B-Braun Tuttlingen, Germany); one Expansys (Mathys Orthopädie GmbH, Meerbusch); and one Meros (Gruppo Bioimpianti S.r.l., Italy). Of the reviewed patients, 24 were curve A (12.3%) and 170 curve B (87.6%). The stem size distribution included 11 patients with size 1 (4.4%); 107 with size 2 (42.6%); 94

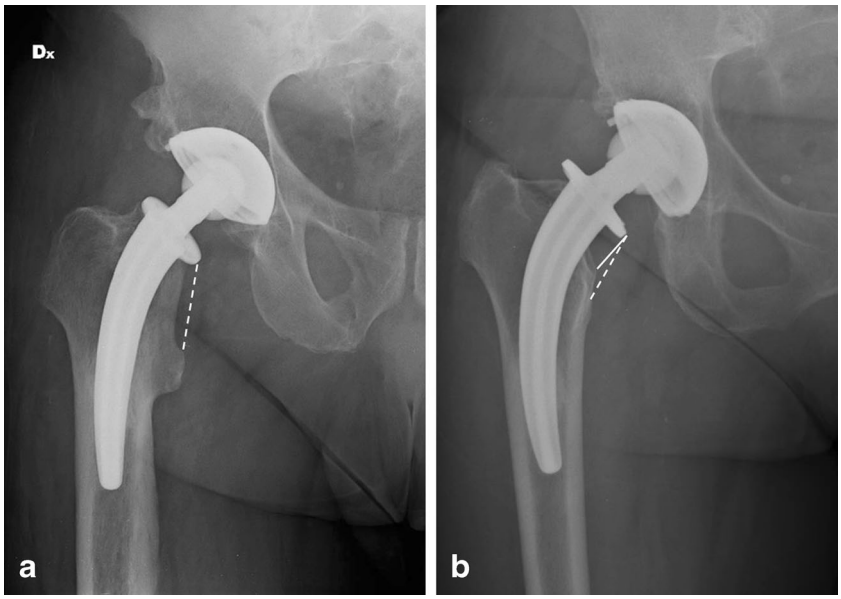

Fig. 1 **a** X-ray analysis 13 years after surgery reveals no neck resorption (NRR = 0); **b** X-ray analysis 14.5 years after surgery showing a severe neck resorption (NRR = 0.71)

with size 3 (37.5%); 14 with size 4 (5.6%); 24 with 5 (9.6%); and one patient with size 6 (0.3%).

Statistical analysis

Continuous variables were reported as mean ± standard deviations. For all analyses, a p-value of <0.05 was considered statistically significant. Association between NRR and main comorbidities/smoke status/bisphosphonate use and between NRR and stem loosening was evaluated by the Fisher test. Correlations between clinical parameters/BMI and NRR were estimated with the Bravais-Pearson correlation coefficient. Correlations between HHS/OHS and NRR were found through linear regression analysis. In order to determine the

Table 1 The table summarizes the main demographic and radiological parameters and their associations with NRR and aseptic loosening

Comorbidities/radiological data	N. of stems	Correlation with NRR	Correlation with aseptic loosening
Diabetes (at least 5 years from diagnosis)	14	$p = 0.56$	$p = 1$
Autoimmune diseases (6 RA, 2 SLE, 1 SS)	9	$p = 0.28$	$p = 0.25$
Steroid therapy (at least 12 months of prednisone or similar >5 mg)	6	$\mathbf{p = 0.002}$	$p = 0.20$
Highly active anti retro viral therapy (HAART)	2	$p = 1$	$p = 1$
Chemotherapy (at least 3 y from the last cycle)	5	$p = 1$	$p = 1$
Hepatopathy (3 patients with HCV related cirrhosis, stage A/B Child-Pugh)	3	$p = 1$	$p = 1$
Sickle cells disease	2	$p = 0.55$	$p = 1$
Chronic kidney disease (grade 3–5, at least 1y from diagnosis, no dialysis)	9	$p = 0.07$	$p = 0.25$
Bisphosphonate therapy (at least 1 year of continuous therapy)	57	$p = 0.5$	$p = 1$
Smoke status (at least 10 cigarettes per day)	48	$p = 0.30$	$p = 0.64$
Varus stem (>5°)	6	$\mathbf{p = 0.01}$	$\mathbf{p = 0.01}$
Valgus stem (>5°)	3	$\mathbf{p = 0.002}$	$\mathbf{p = 0.02}$

In bold type the statistically significant associations. (RA: rheumatoid arthritis, SLE: systemic lupus erythematosus, SS: systemic sclerosis, NRR: neck resorption Ratio)

potential risk of stem aseptic loosening according to the NRR, odds ratios (OR) for different stages of neck resorption were obtained. Inter-observer reliability was evaluated with the Cohen's Kappa coefficient. Survivorship analysis was performed according to the method of Kaplan and Meier using the endpoint for stem revision for any cause.

Results

HHS at the end of f.u. was 89.1 ± 5.7; VAS was 1.1 ± 1; and OHS was 41.3 ± 5.1. Of our patients 96.6% reported an excellent/good result at final f.u. However, seven patients complained of thigh pain. Clinical LLD was 1.5 mm ± 1.9. Radiological evaluation revealed 32 cases of osteolysis (16.1%). Of them 18 were in Gruen zone 1 (56.3%) and nine in Gruen 7 (28.1%). Cortical hypertrophy was observed in 19 stems (9,8%). The global rate of HO was 29.4% with the following distribution according to the Brooker Classification: 27 type 1 (47%); 21 type 2 (36.8%); eight type 3 (14.4%); and one type 4 (1.8%). Mean NRR was 0.35. Of the hips 28.9% revealed a NRR > 0.5. We observed six cases of aseptic loosening, two cases of septic hip revision, one implant revision for recurrent dislocation, and one stem substitution after a B2 periprosthetic hip fracture. No subsidence or intra-operative periprosthethic fracture was observed. The mean time of stem revision was 8.9y ± 5. Three patients underwent a second surgery for heterotopic ossification removal, three for polyethylene liner substitution, and one for ceramic head rupture. We reported one superficial wound infection easily managed with oral antibiotic therapy. One dislocation (1 day after surgery) was treated conservatively. As shown in the Kaplan Meier analysis, the overall survival rate of the stem was 94.8% (Fig. 2). Associations between NRR/aseptic loosening and diabetes, autoimmune diseases, highly active anti-retroviral therapy (HAART), chemotherapy, hepatopathy, sickle cells diseases, chronic kidney disease (CKD), bisphosphonate therapy, and smoker status were not statistically significant. Statistically significant associations were found between varus/valgus and aseptic loosening (p = 0.01 and 0.002 respectively) and varus/valgus and NRR (p = 0.01 and $p = 0.02$ respectively). Association between steroid therapy and NRR/aseptic loosening was $p = 0.001$ and p = 0.20 respectively. Association between aseptic loosening and NRR was $p = 0.002$. Table 1 summarizes the main statistical associations with NRR and aseptic loosening (Table 1).

Correlations between NRR and HHS/OHS were −0.34 and −0.28 respectively (mild correlation, Figs. 3 and 4). The same parameter for VAS was +0.32 (mild correlation). The correlation value between BMI and NRR was +0.02 (no correlation). The same parameter between NNR and years of f.u. revealed a mild correlation (+ 0,32).

OR for aseptic loosening were 4.6 for a NRR > 0.25; 16.9 if > 0.50, and 24.1 if > 0.75. Inter-observer reliability values for radiographic parameters (NRR, osteolysis, HO, cortical hypertrophy, and stem malposition) were 0.95, 0.82, 0.93, 0.98, and 0.95, showing an almost unanimous agreement between surgeons.

Discussion

The major findings of our study include 96.6% of excellent/good clinical results at long-term f.u. with an overall stem survival rate of 94.8%. NRR is directly associated with steroid therapy, stem malposition, and aseptic loosening and fairly negatively correlated with clinical data. We observed a mild positive correlation between NRR and time to surgery showing how this parameter is not the main one that drives neck resorption. The risk of aseptic loosening became strong after 50% of neck resorption. Our findings contribute to the exsiting body of literature concerning the use of a CFP stem.

The use of a conservative femoral component in total hip replacement is not new [14, 15]. In his pioneering studies, Pipino advocated neck preservation as a part of the more general philosophy of TSS. He was the first to list TSS milestones [16] and to understand the importance of neck retention. In 2006, Pipino and Keller [7] reported clinical and radiological outcomes of patients treated with femoral neck preserving arthroplasties. Nine hundred forty-three implants of two different neck-preserving stems (Biodynamic and CFP) were retrospectively reviewed. The authors observed excellent results in 97% of patients and an optimal survival rate. Further studies have been carried out with CFP stem.

Briem et al. [17] reviewed a consecutive series of 155 patients who underwent THA with the CFP stem at a mean f.u. of 6.2 years. They reported good to excellent mid-term clinical results in 96% of patients with no thigh pain, although six stems were implanted in varus. Eight patients were revised, mainly for periarticular ossifications or recurrent dislocation, with only one patient affected by early aseptic loosening. Our data support Briem et al.'s findings. Hutt et al. [18] conducted a prospective cohort study including 75 CFP implants. Patients were followed for a mean of 9.3 years. Good to excellent clinical results were reported. No radiological changes were assessed at the end of follow-up and only four cases (11%) showed stem subsidence. For the stem, the ten year survival was 100%. In a recent study, You et al. [19] followed 46 patients (mean age 41.5 years) treated with CFP prosthesis for an average time of 7.6 years. They reported a mean HHS of 82.3 with good restoration of LLD. Six patients sustained perioperative complications (one post-operative dislocation and five intra-operative femoral fractures). Recently, Li et al. [20] focused their attention on complications related to CFP hip stem; 142 hips were followed up for a mean of 4.72 years.

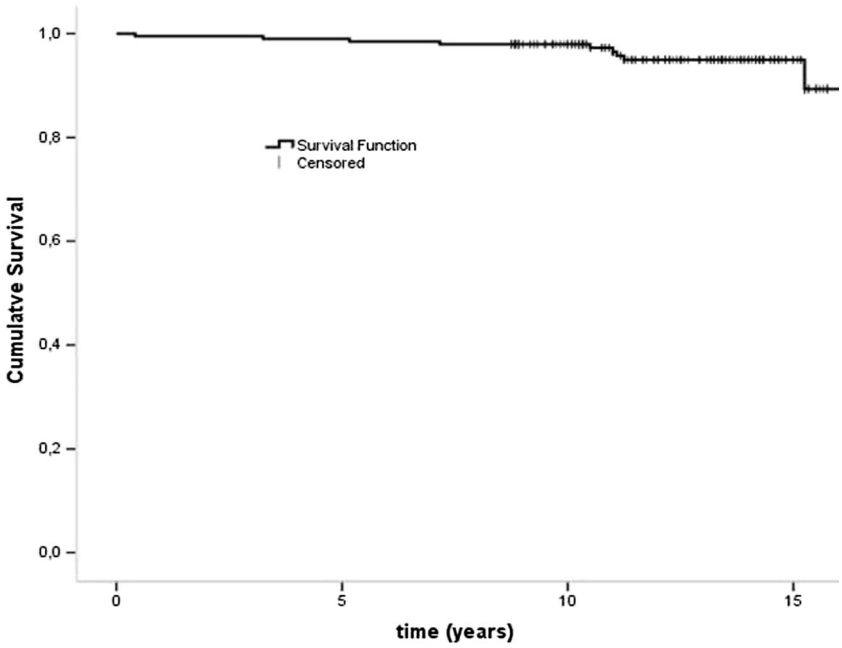

Fig. 2 Kaplan-Meier survival curve including the 95% confidence interval with time and probability of survivorship of CFP stem for any reason of revision

A posterolateral approach was used in all cases. Proximal femoral bone loss was observed in five patients and mild heterotopic ossification occurred in four cases. No thigh pain, stem loosening or subsidence were reported. Intra-operatively, ten fractures at the tip of the stem occurred. Despite the encouraging results, the short follow-up period does not allow for drawing definite conclusions.

Although many studies have been conducted regarding its use, CFP is not the only neck preserving femoral stem [8, 21, 22]. Literature concerning other neck preserving short stems reveals data that are comparable with that of the present study [23]. In particular, our mean revision per 100 observed components years was 0.26, in line with the average of this parameter related to partial collum stems [24]. In our cohort of patients, NRR >0.5 was observed in 28.9% of hips. Some authors argue that short femoral stems provide more femoral bone stock preservation than conventional ones by loading femur more proximally. Nevertheless, data regarding

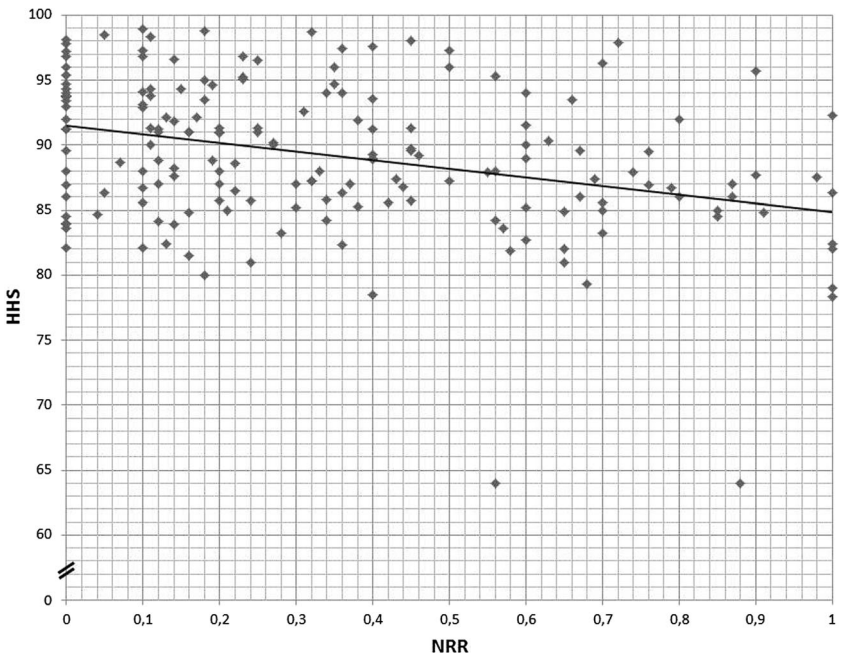

Fig. 3 Linear regression analysis showing the correlation between Harris hip score (HHS) and neck resorption ratio (NRR)

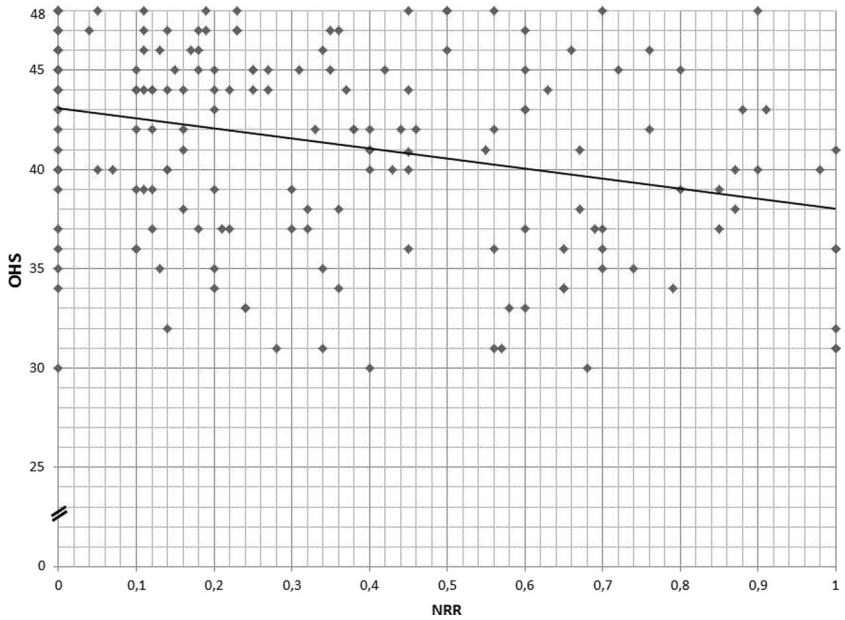

Fig. 4 Linear regression analysis showing the correlation between Oxford hip score (OHS) and neck resorption ratio (NRR)

periprosthetic bone mineral density (BMD) preservation around CFP stem are unclear and confusing [25, 26]. Our results showed that NRR is statistically correlated to steroid therapy and stem malposition and fairly related to time from surgery. Moreover, NRR has a moderate correlation with clinical results at long-term f.u.

Correlation between proximal femoral bone loss and incidence of stem loosening is still debated [27]. We observed 84.4% cases of osteolysis in the proximal femoral region (Gruen zone 1 and 7). These data could be due to the great metaphyseal osteointegration. Theoretically, this behavior unloads the calcar region and could lead eventually to a bone mineral density reduction in this anatomical area. Nevertheless, at long-term f.u., we noticed a statistically significant correlation between NRR and aseptic loosening if NRR >0.5 (OR: 16.9). When the neck is widely reabsorbed, stem stability is guaranteed only by the metadiaphyseal cylinder. For our study, neck resorption does not imply stem loosening but rather, a higher risk of future aseptic loosening. Moreover, NRR should be considered an easy-to-use radiological prognostic parameter of CFP stem evaluation and could be possibly broadened to other neck-preserving stems. According to our evidence, we advise a stricter f.u. in the subgroup of patients with a NRR > 0.5.

To our knowledge, no data regarding CFP stem results over an f.u. period as long as the one used for this study are available in literature. Moreover, this is the first report that provides evidence about neck resorption and its possible consequences in this kind of stem. Undoubtedly, our study has several limitations including the lack of preoperative clinical evaluation and drop-out percentage. In addition, the association between NRR and some demographic data should be confirmed by high quality studies with proper power analysis.

Conclusion

The CFP hip stem demonstrates effective clinical and radiological results at long-term follow-up. Neck resorption is directly associated to steroid therapy, stem malposition, and fairly correlated with time to surgery. NRR is significantly related to aseptic loosening and moderately correlated to clinical data. The risk of aseptic loosening increases according to NRR. According to our data, we advise a stricter f.u. in patients with NRR >0.5 in order not to miss possible early stem loosening. We suggest the use of NRR as a reliable and simple prognostic radiological parameter of aseptic loosening in the periodic evaluation of neck preserving stems.

Compliance with ethical standards

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

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Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Informed consent Informed consent was obtained from each individual participant included in the study.

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