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ORIGINAL PAPER

Cementless revision femoral stems application of press-fit principles and clinical outcomes

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Abstract

Background Cementless femoral stems are currently used in revision total hip arthroplasty (THA) with the surgeon choosing between various fixation modes. The outcomes are good in the medium term; however, some failures have been attributed to technical errors during implantation. When the decision has been made to use a press-fit implant, the impact of the surgeon's technique on the functional outcomes have not been explored in-depth. This led us to carry out a retrospective study on a large population of total hip arthroplasty patients which aims were achieved press-fit to (1) determine the impact of the type of primary fixation (with and without press-fit) on the functional outcomes; (2) specify the effect of stem length on the functional scores when diaphyseal press-fit is achieved and (3) analyse the main reasons why a true press-fit effect was not achieved (three-point fixation).

Hypothesis There is a relationship between the primary fixation method by press-fit of a revision femoral stem and the functional outcomes.

Patients and methods We performed a retrospective analysis of a continuous cohort of 244 THA revision cases with a mean follow-up of 6.1 ± 3.5 years (range, 2–18). The femoral area in which close contact was achieved (shared interface between the bone and implant) was used to define various types of press-fit fixation. The functional outcomes were determined using the Harris Hip Score (HHS) and the Merle d'AubignéPostel score (MAP score) out of 12 points (pain and walking items).

Results The post-operative HHS averaged 90.83 ± 7.51 for proximal press-fit and 80.14 ± 14.93 with no press-fit ($p = 0.01$). The MAP averaged 10.83 ± 1.03 for proximal press-fit and 9.75 ± 2.09 with no press-fit ($p = 0.09$). The MAP score was worse for long diaphyseal press-fit than for short press-fit ($p = 0.02$). Use of a long stem with an endofemoral route or an overly small femoral window in patients with a curved femur is the main reason that three-point fixation occurred instead of press-fit.

Conclusions While press-fit is an effective concept, it is a demanding one that requires the surgeon to choose the correct surgical strategy for the patient's anatomy. A meticulous surgical technique is required to achieve proximal press-fit or at a minimum, short diaphyseal press-fit.

Keywords Arthroplasty · Revision · Press-fit stem · Fixation zone · Functional results

Introduction

When the decision is made to use a cementless stem to revise the femoral side of a failed THA, the first step is to select a design that ensures good primary fixation. Various cementless femoral revision stem designs are available. Distal locking stems [1] were specially designed for revision surgery, especially when the surgeon believes that fixation can only be

Level of Evidence: Level IV, therapeutic study

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achieved in the distal third of the femur. However, there are few indications for this design or that of custom-made stems. The most commonly used stems have a "fit and fill" [2–4] or "press-fit" [5–8] design. For these two designs, close contact between the bone and implant in the form of a planar interface is essential. In addition, a press-fit stem must be perfectly wedged into the bone. These two designs typically consist of a one-piece primary stem that has been lengthened [9]. More recently, modular femoral stems specific to revision procedures have been introduced [10, 11]. Some revision stems combine several concepts [12]: anatomical, modular, lockable.

Practical application of the chosen design can vary from one surgeon to another. We felt it was relevant to study which factors impact the functional outcomes. Our team prefers the press-fit concept and a straight, modular stem with conical configuration [13]. This led us to carry out a retrospective study on a large population of total hip arthroplasty patients which aims were achieved press-fit to (1) determine the impact of the type of primary fixation (with and without press-fit) on the functional outcomes; (2) specify the effect of stem length on the functional scores when diaphyseal press-fit is achieved and (3) analyse the main reasons why a true press-fit effect was not achieved (three-point fixation).

Patients and methods

Patients

This was a retrospective study of 244 continuous THA cases undergoing revision between 1996 and 2003 (234 patients). Fourteen patients died (6%), 9 (4%) were lost to follow-up and 20 (8%) could only be evaluated by telephone. Five cases (2%) were excluded because the revision was performed for a periprosthetic fracture. At the end, 196 hips (80%) in 187 patients were analysed for this study (9 bilateral revisions). These hips underwent a full radiological and clinical evaluation after a minimum follow-up of two years.

There were 101 women and 86 men (80 left hips and 116 right hips).The mean age was 69.6 ± 9.1 years (27–89) and the mean follow-up was 6.1 ± 3.5 years (2–18).The revision procedures were performed because of femoral aseptic loosening in 99 cases (51%), extensive femoral granuloma in 38 cases (19%), cup loosening with femoral stem change in 55 cases (28%), broken femoral stem in two cases and recurring dislocation in two cases. The femoral loosening was recurrent in 30 patients (15%) and 16 cups (8%) were not changed.

Surgical technique

The procedures were performed by two senior surgeons (PLB and MG) who use the same press-fit femoral stem implantation method. An anterolateral approach was used 26 times and a posterolateral one in 170 cases. The femur was exposed using an endofemoral approach in 49 cases and a femorotomy (trochantero-diaphyseal femoral flap) in 147 cases.

When proximal fixation was the goal (12 cases), intramedullary corticocancellous bone or a bone substitute was used in eight cases (Fig. 1). The implant used was modular, wedge-shaped, straight cementless femoral stem (Revitan™, Zimmer, Warsaw, IN) and made of titanium alloy with a thin grit-blasted surface finish that was suitable for bone integration along its entire length. During the post-operative course, the patients were allowed to partially bear weight on the operated limb for the first two weeks, whether femoral osteotomy had been performed or not.

The primary fixation area by press-fit was determined on immediate post-operative A/P radiographs. To determine the various types of primary press-fit, the location of bicortical contact was defined as the interface between the femur bone and the implant according to Morscher [14]. The primary fixation was proximal in the metaphysis (Fig. 1) or at the metaphysis-diaphysis junction in 12 cases, global in 18 cases, diaphyseal in 117 cases (Fig. 2) and lacking press-fit in 49 cases; in the latter cases, the primary stability was achieved by three-point contact with no continuous interface between the bone and implant.

Outcome assessment

The functional outcomes were determined using the Harris Hip Score (HHS) [15] and the Merle d'AubignéPostel score (MAP score) [16] out of 12 points (pain and walking items). The clinical outcomes at the final follow-up visit took into consideration both components of the THA. The outcomes were determined according to each type of primary fixation defined above (Table 1).

For the 117 cases in which diaphyseal press-fit was achieved, the relationship between outcomes (HHS and MAP) and implant length was determined. For this study, the cases were separated into those receiving a short femoral stem (length ≤ 250 mm) or a long stem (length > 250 mm):

- A short stem was used in 83 cases (71%) (Fig. 2). In this sub-group, 35 patients had full press-fit after additional proximal stabilisation of the implant on a window [17], while 48 patients had only diaphyseal press-fit. These two sub-groups were the subject of a separate analysis.
- A long stem was used in 34 patients (29%). In this sub-group, 16 had full press-fit while 18 patients did not have proximal stabilisation of the implant. These two sub-groups were also the subject of a separate analysis (Table 2).

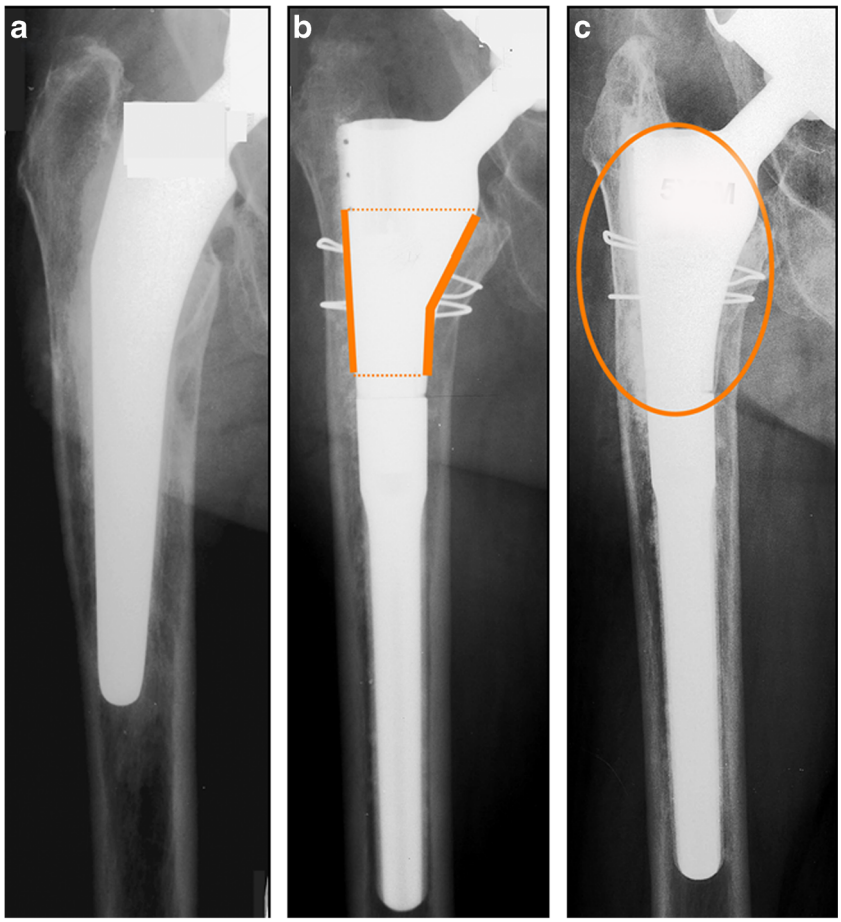

Fig. 1 **a** Female, 71 years of age, THA of the right hip, 14 years' follow-up. Cup loosening and revision of cemented femoral stem; a few small granulomas are present at the medial cortex of the femur. Osteopenia with a low cortical index of 0.33. **b** Endofemoral approach and implantation of a cementless stem with proximal press-fit after adding intramedullary corticocancellous bone graft in the metaphysis area and performing wire cerclage of the femur. **c** 6-year follow-up: good clinical outcome with HHS score of 85/100 and MAP of 10/12. Complete proximal osseointegration of the stem, and no significant stress shielding in the diaphysis portion

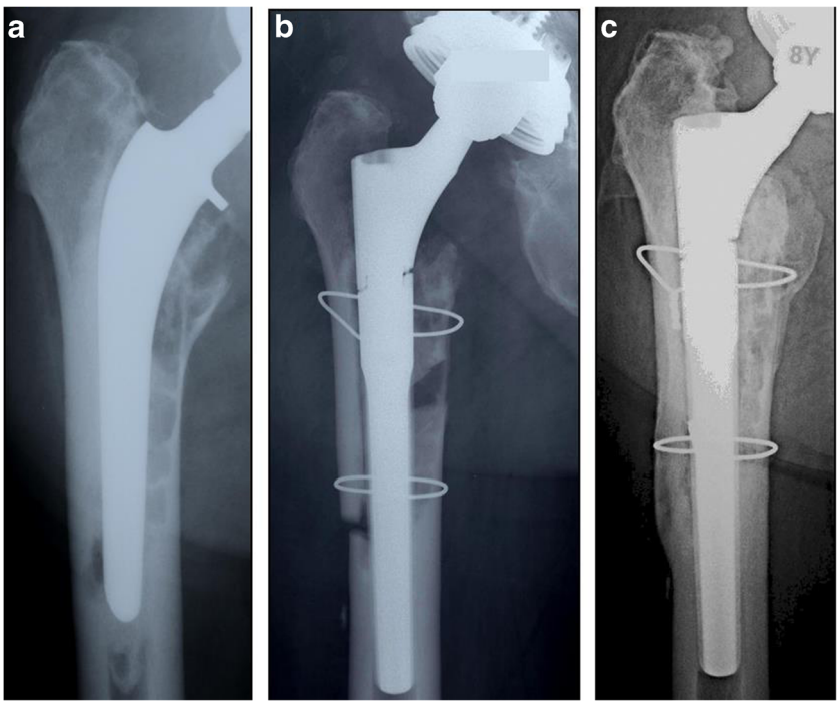

Fig. 2 **a** Male, 70 years of age, THA of the right hip, 11 years' follow-up. Significant bone destruction of the medial cortex by granulomas. Cortical index good at 0.60, thus no osteopenia. **b** A 15-cm-long lateral trochantero-diaphyses bone window was made. Short but full diaphyseal press-fit over 33 mm of the proximal femur after osteotomy of the medial cortex. No bone graft was used. **c** 8-year follow-up: excellent clinical outcome with HHS of 97/100 and MAP score of 12/12. Very good regeneration of the bone stock; however, a proximal osseointegration defect is visible

Table 1 Clinical outcomes based on type of primary fixation

Type of primary fixation	Harris Hip Score				Merle d'AubignéPostel score			
	Preop.	Postop.	Difference	*P*	Preop.	Postop.	Difference	*P*
Proximal press-fit ($n = 12$)	53.17	90.83	+ 37.67	$p = 0.01$ (1)	7.16	10.83	+ 3.67	$p = 0.09$ (1)
Global press-fit ($n = 18$)	45.78	87.94	+ 42.17	$p = 0.04$ (2)	6.44	10.50	+ 4.06	$p = 0.16$ (2)
Diaphyseal press-fit ($n = 117$)	44.11	82.62	+ 38.50		6.07	10.24	+ 4.17	
No press-fit (3-point fixation) ($n = 49$)	46.76	80.14	+ 33.39		6.35	9.75	+ 3.40	

(1) Comparison of proximal fixation versus 3-point fixation

(2) Comparison of global fixation versus 3-point fixation

For the 49 cases in which a true press-fit effect was not achieved (three-point fixation), the relationship between the femoral approach (endofemoral in 15 cases and femoral window in 34 cases) and the femur shape and stem length was determined (Table 3). The femur shape was determined on AP radiographs; after drawing the intramedullary axis in the images, the femur was said to be curved if it was lateralised or medialised in the metaphysis area. When a femoral window was used, its length was defined as the distance between the tip of the greater trochanter and the window's distal edge. The cases were divided into two sub-groups based on the window length being more or less than 130 mm, as in the De Menezes et al. study [18].

Statistical methods

All quantitative measurements were analysed with the EvalNet software (LeadTools™; LEAD Technologies, Inc., Charlotte, NC, USA) whose precision has been confirmed [18]. All statistical analyses were performed using the statistical software programme SAS (version 9.3, SAS Institute Inc., Cary, NC, USA). The independence of two qualitative variables in non-paired groups was tested using the chi-square (or Fisher's exact test, if needed). Student's *t* test was used with parametric data (HHS and MAP scores).

Results

By type of primary fixation (Table 1)

Overall, the post-operative HHS and MAP scores were significantly improved in the cases with proximal and global press-fit, and less improved in cases with diaphyseal press-fit. In the cases in which no press-fit was achieved (three-point fixation), the HHS was significantly worse by 10.69 points relative to proximal press-fit ($p = 0.01$) and by 7.8 points relative to global press-fit ($p = 0.04$).

By type of diaphyseal press-fit (Table 2)

For the 34 cases (29%) with a long stem, the press-fit interface averaged 37.68 mm ± 13.78 (15–75) in length. For the 83 cases (71%) with a short stem (Fig. 2), the press-fit interface averaged 35.8 mm ± 12.5 (5–75) in length.

If the outcomes of short press-fit (83 cases) and long press-fit (34 cases) are compared, the post-operative HHS and MAP

Table 2 Clinical outcomes based on type of diaphyseal press-fit

Diaphyseal press-fit	Harris Hip Score				Merle d'AubignéPostel score			
	Preop.	Postop.	Difference	*P*	Preop.	Postop.	Difference	*P*
Short stem ($n = 83$)	46.48	83.87	+ 37.39	$p = 0.08$ (1)	6.30	10.39	+ 4.09	$p = 0.10$ (1)
Full ($n = 35$)	47.11	83.34	+ 36.23		6.34	10.26	+ 3.92	
Incomplete ($n = 48$)	46.02	84.25	+ 38.23	$p = 0.55$ (2)	6.27	10.48	+ 4.21	
Long stem ($n = 34$)	38.32	79.56	+ 41.24	$p = 0.07$ (3)	5.5	9.91	+ 4.41	$p = 0.02$ (3)
Full ($n = 16$)	39.75	81.19	+ 41.44		5.87	10.19	+ 4.31	
Incomplete ($n = 18$)	37.06	78.11	+ 41.05		5.17	9.67	+ 4.5	

(1) Comparison of post-operative HHS and MAP score between short stem and long stem

(2) Comparison of post-operative HHS and MAP score between full short stem and full long stem

(3) Comparison of post-operative HHS and MAP score between incomplete short stem and incomplete long stem

Table 3 Three-point fixation: important anatomical and surgical features

Femoral approach ($n = 49$)	Femur shape		Implant length	
	Straight	Curved	Short < 250 mm	Long > 250 mm
Endofemoral ($n = 15$)	7	8	5	10
Femoral window ($n = 34$)				
Length ≤ 130 mm ($n = 16$)	3	13	12	4
Length > 130 mm ($n = 18$)	8	10	10	8

scores were clearly improved in the short stem cases; the HHS score was 4.31 points better *($p = 0.08$)* and the MAP score was 0.48 points better *($p = 0.10$)* than in the long-stem cases.

This difference is greater when the diaphyseal press-fit was incomplete; for the 18 cases with incomplete long press-fit, there was a 6.14-point difference with incomplete short press-fit *($p = 0.07$)* for the HHS score and a significant difference of 0.81 points *($p = 0.02$)* for the MAP score.

No press-fit (three-point fixation: 49 cases) (Table 3)

For the 15 cases performed by the endofemoral approach, the femur was curved in eight cases (53%) and a long stem was used in ten cases (67%). When a trochantero-diaphyseal femoral window was made (34 cases), it was less than or equal to 130 mm in length in 13 cases when the femur was curved (57% of cases); based on a study by Menezes [18], this may be insufficient to reduce the femoral curvature. The lowest post-operative HHS was in the 16 cases of three point fixation with a short window: 77.88 ± 18.55 (22–99) versus 78.11 ± 13.59 (51–96) for incomplete long diaphyseal press-fit.

Discussion

Clinical scores based on type of press-fit and implant length

Good clinical outcomes were achieved in the cases with proximal press-fit and to a lesser degree, short diaphyseal press-fit. In prior studies [19–21], our group showed that these primary fixation modes lead to the best radiological outcomes, especially for secondary bone fixation.

The clinical outcomes achieved in the cases with a long stem and diaphyseal press-fit were less good, especially when no additional proximal stabilisation was added to the stem (Table 2). To explain these finding, we can point to the larger bone-implant interface with the long stem (37.68 mm vs 35.8 mm for a short stem). This can alter the transmission of femur stresses in flexion and reduce the bone density, with the latter being responsible for a decrease in clinical scores, especially in the context of osteopenia [22].

Use of a straight, conical stem is a good way to achieve true press-fit [13, 14]. The straight stem ensures bone-implant contact over a planar interface, while the conical shape provides wedging or bracing [23] at the interface, greater pressure (or pre-load) against the destabilising forces such as stresses that encourage sinking and/or rotation.

The press-fit concept is suitable for a large number of cases, both primary and revision THA. Proximal fixation can be achieved in the proximal or diaphyseal area of the femur over a short distance. This is where the greatest distinction exists between press-fit and fit and fill designs, with the latter corresponding to a straight, cylindrical stem that is stabilised in the isthmus area over several centimetres, which can increase the risk of stress-shielding [24].

There are other cementless stem designs. With distally locked stems, proximal fixation is problematic. Use of a long stem is a general rule and unlocking is theoretically desirable so as to not alter the transmission of flexion loads to the femur too much.

For modular stems, the lower strength of these implants at the junction of the two components is well known [25, 26]. If complete bone regeneration does not occur, the assembly mechanism can fail, like in one of our patients.

With curved stems, one of the drawbacks is that the femur's curvature may not match that of the stem. The need to combine several concepts in one implant (curvature, locking, modularity) is a drawback because the weak points of each concept are added up. As for custom stems, they are very costly to manufacture. While the design theoretically matches the medullary canal exactly, these implants are invasive and may damage the bone stock.

Three-point fixation and no press-fit

The fact that no press-fit was achieved in 25% of our cases means that true press-fit is difficult to achieve. Other than the fact that three-point fixation leads to worse clinical outcomes, of the four patients in our study who required an early revision, two had no press-fit, thus little control over rotational stresses.

Among the main reasons for three-point fixation are incomplete removal of the cement in the diaphysis (5 cases), implantation of a long stem by the endofemoral route in a

Table 4 Change in Harris Hip Score based on length of follow-up

	Harris Hip Score			
	Pre-op.	Post-op.	Difference	*p* (Student's *t* test)
< 48 months Mean: 36.4 months *n* = 61	42.3	81.79	+ 39.44 ± 15.9	0.43
49–81 months Mean: 61.8 months *n* = 74	46.7	82.82	+ 36.04 ± 13.73	
≥ 82 months Mean: 126.1 months *n* = 61	47.0	84.39	+ 37.36 ± 16.98	

patient with minimal femur curvature and making the bone window too short to reduce the femur curvature.

Press-fit is a demanding concept [13, 27]; thus, several rules must be followed during the surgical procedure to avoid three-point fixation. First, it is important to be near the anchoring zone during its preparation. Thus, an endofemoral approach is indicated if proximal anchoring is feasible, which is typically the case in primary THA. If diaphyseal anchoring is the only option—particularly during revision THA—a femoral window is often preferable. Second, it is important to work on a straight portion of the femur; while a reamer can remove an obstacle, it cannot straighten out a curved femur. In this scenario, a lateral trochantero-diaphyseal window that averages 15 cm in length is needed, often in combination with medial corticotomy to achieve a "global fit" [17]. Third, it is important to work over a short distance (20 to 40 mm) to achieve the best possible interface, which, among others, contributes to perfect wedging. In our cohort, the mean length of the diaphyseal press-fit zone was 36.3 mm.

Study limitations

The main limitation of this study is that some patients may have had acetabular involvement, which would compromise the functional outcomes. Another limitation is insufficient follow-up after the revision procedure in some cases. To assess the impact of this limitation, we performed a secondary analysis on three groups of patients based on the mean revision time (Table 4). After a mean follow-up of three years, it is reasonable to assume that the clinical score will not change significantly (unless the patient has an accident).

Conclusions

To ensure good primary fixation of a cementless femoral stem, the press-fit design is effective but demanding. It requires that the surgical strategy be adapted to the patient's anatomy and that a meticulous surgical technique be used to avoid three-point fixation. The aim should be to achieve proximal or short diaphyseal fixation whenever possible.

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Compliance with ethical standards

Conflict of interest FC certifies that he has or may receive payments or benefits from a commercial entity (Zimmer Educational).

SP certifies that he has or may receive payments or benefits from a commercial entity (Tornier Corin).

LD and LC have nothing to declare.

PLB certifies that he has or may receive payments or benefits from a commercial entity (Zimmer GmbH) that may be perceived as a potential conflict of interest.

Ethical board review statement Each author certifies that his or her institution has approved or waived approval for the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research.

Location of the work This work was performed at CHU Montpellier.

References

1. Mertl P, Philippot R, Rosset P, Migaud H, Tabutin J, Van de Velde D (2011) Distal locking stem for revision femoral loosening and periprosthetic fractures. Int Orthop 35:275–282
2. Daiki I, Nishii T, Miki H, Sugano N, Sakai T (2008) Proximal bone remodelling differed between two types of titanium long femoral components after cementless revision arthroplasty. Int Orthop 32: 431–436
3. Engh CA, Bobyn JD, Glassman (1987) Porous-coated hip replacement. The factors governing bone ingrowth, stress shielding, and clinical results. J Bone Joint Surg 69B:45–55
4. Paprosky WG, Greidanus NV, Antoniou J (1999) Minimum 10-year-results of extensively porous-coated stems in revision hip arthroplasty. Clin Orthop Relat Res 369:230–242
5. Amanatullah DF, Howard JL, Siman H, Trousdale RT, Mabry TM, Berry DJ (2015) Revision total hip arthroplasty in patients with

extensive proximal femoral bone loss using a flutedtapered modular femoral component. Bone Joint J 97-B:312–317
6. Böhm P, Bischel O (2001) Femoral revision with the Wagner SL revision stem. Evaluation of one hundred and twenty-nine revisions followed for a mean of 4,8 years. J Bone Joint Surg Am 83-A: 1023–1031
7. Van Houwelingen AP, Duncan CP, Masri BA, Greidanus NV, Garbuz DS (2013) High survival of modular tapered stems for proximal femoral bone defects at 5 to 10 years followup. Clin Orthop Relat Res 471:454–462
8. Wirtz DC, Gravius S, Ascherl R, Forst R, Noeth U (2014) Uncemented femoral revision arthroplasty using a modular tapered, fluted titanium stem. 5- to 16- year results of 163 cases. Acta Orthop 85:562–569
9. Korovessis P, Repantis T (2009) High medium-term survival of Zweymüller SLR-plus® stem used in femoral revision. Clin Orthop Relat Res 467(8):2032–2040
10. Brown NM, Tetreault M, Cipriano CA, Della Valle CJ, Paprosky W, Sporer S (2015) Modular tapered implants for severe femoral bone loss in THA: reliable osseointegration but frequent complications. Clin Orthop Relat Res 473:555–560
11. Cross MB, Paprosky WG (2013) Managing femoral bone loss in revision total hip replacement. Fluted tapered modular stems. Bone Joint J 95-B(Supple A):95–97
12. Fink B, Grossmann A, Fuerst M (2010) Distal interlocking screws with a modular revision stem for revision total hip arthroplasty in severe bone defect. J Arthroplast 25:759–765. https://doi.org/10.1016/j.arth.2009.05.019
13. Le Béguec P, Canovas F, Roche O, Goldschild M, Batard J (2015) uncemented femoral stems for revision surgery. Springer international Publishing, Heidelberg
14. Morscher E (1991) Experience with the press-fit cup and press-fit gliding stem. In: Kusswetter W (ed) Noncemented total hip replacement. Proceedings of International Symposium. Tübingen, Germany. New York, Stuttgard: Thieme. p 221–31
15. Harris WH (1969) Traumatic arthritis of the hip after dislocation and acetabular fracture. Treatment by moldarthroplasty. An end result study using new method of result evaluation. J Bone Joint Surg Am 51:737–754
16. D'Aubigné RM, Postel M (1954) Functional results of hip arthroplasty with acrylic prosthesis. J Bone Joint Surg Am 36A: 451–475
17. Canovas F, Le Beguec P, Batard J, Gaillard F, Dagneaux L (2017) Global fit concept in revision hip arthroplasty for cementless press-fit femoral stems. Orthop Traumatol Surg Res 103(4):579–581. https://doi.org/10.1016/j.otsr.2017.01.015
18. De Menezes DF, Le Béguec P, Sieber HP, Goldschild M (2012) Stem and osteotomy length are critical for success of the transfemoral approach and cementless stem revision. Clin Orthop Relat Res 470:883–888
19. Canovas F, Girard J, Roche O, Migaud H, Bonnomet F, Goldschild M, Le Béguec P (2015) Bone stock in revision femoral arthroplasty: a newevaluation. Int Orthop 39:1487–1494
20. Canovas F, Putman S, Girard J, Roche O, Bonnomet F, Le Béguec P (2018) Global radiological score for femoral cementless revision stem. Int Orthop 42(5):1007–1013
21. Roche O, Girard J, Canovas F, Migaud H, Bonnomet F, Goldschild M, Le Béguec P (2016) Assessment of fixation in cementless femoral revision of total hip arthroplasty:comparison of the Engh score versus radiolucent line measurement. Int Orthop 40:907–912
22. Canovas F, Roche O, Girard J, Bonnomet F, Goldschild M, Le Béguec P (2015) Bone density and functional results after femoral revision with a cementless press-fit stem. Orthop Traumatol Surg Res 101:195–199
23. Girard J, Roche O, Wavreille G, Canovas F, Le Béguec P (2011) Enfoncement secondaire d'une tige de révision fémorale: à propos d'une série de 183 cas au recul moyen de 5.5 ans. Orthop Trauma Surg Res 97:121–126
24. Bugbee WD, Culpepper WJ, Engh CA Jr, Engh CA Sr (1997) Long-term clinical consequences of stress-shielding after total hip arthroplasty without cement. J Bone Joint Surg Am 79-A:1007–1012
25. Konan S, Garbuz DS, Masri BA, Duncan CP (2016) Modular tapered titanium stems in revision arthroplasty of the hip: the risk and causes of stem fracture. Bone Joint J 98-B(1 Suppl A):50–53
26. Lakstein D, Eliaz N, Levi O, Backstein D, Kosashvili Y, Safir O, Gross AE (2011) Fracture of cementless femoral stems at the mid-stem junction in modular revision hip arthroplasty systems. J Bone Joint Surg Am 93:57–65
27. Le Béguec P, Goldschild M, Roche O, Sieber HP (2008) The press-fit concept : an effective but demanding concept. Interact Surg 3: 89–96