Removal of well-fixed fixed femoral stems

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A B S T R A C T

The removal of a well-fixed prosthetic stem raises technical challenges. The objective is not only to remove the material, but also to prepare the implantation of a new prosthesis. Cemented stems are only very rarely unremovable; extraction of the cement mantle and plug raises the greatest difficulties. The main risk is cortex perforation, and a radiograph should be obtained at the slightest doubt. The removal of cementless stems carries a higher risk of fracture. Difficulties should be anticipated based on thorough familiarity with the implant design and on evaluations of implant fixation and bone stock. The intramedullary approach is usually sufficient to extract a cemented or cementless, well fixed, standard stem. Routine use of a transfemoral approach is warranted only in the following situations: revision surgery for infection, S-shaped stem, long stem, curvature or angulation of the femoral shaft, or unfeasible hip dislocation. However, the possibility that the intramedullary approach may need to be converted to a transfemoral approach should be anticipated. Thus, preoperative planning must include determination of the optimal length of a femoral osteotomy or femoral flap, should one be needed, and the surgeon must have access to all the revision implants and tools that might be needed for re-implantation. Experience with the various techniques is indispensable, as a well-performed extensive approach is associated with less morbidity than a fracture or trajectory error. There are three main techniques, which are described here: intramedullary extraction of a cementless stem, intramedullary extraction of a cemented stem, and transfemoral extraction through an extended trochanterotomy. The patients should receive detailed information on the difficulties of femoral stem removal and on the available solutions.

1. Introduction

Extracting a well-fixed femoral stem of a hip prosthesis is challenging [1,2]. A study of 1398 femoral revisions reported at the 1999 SoFCOT symposium [3] showed intraoperative fractures in 12% and cortex perforation in 5% of cases. To prevent these complications, close attention should be directed [4,5] to the reason for revision, the implants to be revised, and the corresponding extraction techniques. Then, the approach and revision prosthesis should be selected with care. This method allows the surgeon to determine the optimal strategy. Without being overly pessimistic, the worst-case scenario should be considered in order to anticipate and to prevent possible complications.

2. When does a well-fixed stem require removal?

During hip revision surgery, preserving a well-fixed stem decreases the risk of further bone damage and complications [6]. The surgeon must have access to all the necessary material (trial and permanent heads with various depths and diameters, modular necks, and acetabular inserts) and check that the acetabular and femoral components can be used in combination, based on the bearing-surface couple and manufacturer(s). For instance, in revisions for hip instability, the head and/or neck can be changed [7] or the acetabular implant replaced by a dual-mobility cup [8].

Extraction of the femoral stem is required in two situations:

- planned femoral revision:
  - breakage of the stem or neck (Fig. 1) always requires stem extraction [9],
  - in patients with chronic infection [10], the stem and all the cement must be removed through an extended trochanteric osteotomy (ETO), which is the only approach that provides access to the intramedullary cavity and allows complete excision of all infected tissues,
  - when cup revision is required, the presence of femoral osteolysis, particularly if progressive, indicates a preference for stem exchange, as progression of the osteolysis would increase the difficulty of subsequent femoral revision;

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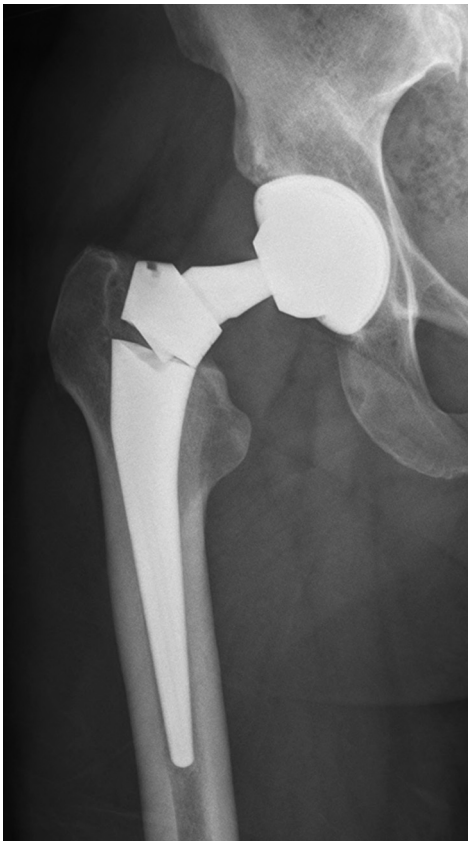

Fig. 1. Fracture of a femoral stem prolonged by a modular neck.

- unplanned femoral revision:
  The decision to revise the femoral component may be taken intraoperatively, for any of the following reasons:
  - planned cup revision during which lower-limb length proves impossible to adjust,
  - instability that cannot be managed by using a modular femoral head and changing the orientation of the cup (e.g., because of excessive or insufficient stem anteversion),
  - head-cup incompatibility (excessively wide neck likely to induce a cam effect, or mismatch between the femoral head diameter and the new cup) or,
  - damage to the stem (alterations of the neck or Morse taper, monoblock stem with a damaged head).

Ideally, these scenarios should be anticipated to allow information of the patient and optimal preparation of the procedure (anaesthesia, material).

3. The problem

The surgeon must devise the optimal surgical strategy for removing the well-fixed stem and, if present, the cement mantle, without damaging the femoral bone, in order to produce good conditions for implanting a new prosthesis. The first step in developing this strategy consists in answering the following five questions.

3.1. What is the expected level of difficulty of stem extraction?

Thorough familiarity with the characteristics of the implant and a detailed preoperative radiographic assessment are indispensable [3]. The surgical report must be obtained, as well as the exact references of the implant (giving the patient a medical-device tracking document was made mandatory in France by a decree issued on 29 November 2006) to identify parameters such as the maker, model, year of manufacture, mode of fixation, characteristics of the coating if any, and specific extraction instruments.

The radiographs should include a view of the pelvis and anteroposterior and lateral views of the entire femur, and the magnification factor should be recorded to allow determination of the following ten parameters:

- femoral axis and whether the femur is straight or curved in the coronal or sagittal plane, with the apex of the curvature;
- axis of femoral stem implantation and shape (i.e., high-profile shoulder or low-profile sabre-like shoulder);
- shape of the greater trochanter and whether this structure covers or projects over the implantation axis of the femoral stem;
- whether the greater trochanter is remodelled or the site of non-union;
- centring of the femoral stem;
- stem anchoring sites, which depend on the length and shape of the stem, the condition of its surface, and its coating;
- areas of fragile bone (focal or diffuse osteolysis);
- the characteristics of the cement plug, including its length ($<$ or $\geq$ 30 mm), centring, or pedestal;
- presence of any obstacles (screws, cerclage wires, internal fixation material);
- potentially difficult or high-risk dislocation.

Factors that influence ease of extraction include the stem shape (e.g., extent to which the stem fills the canal, width of the shoulder, curvature, flange), stem length, characteristics of the stem surface (microporous, gross irregularities), presence and extent of a coating, and strength of the fixation.

3.2. Which approach should be used?

A discussion of this issue can be found in an instructional course lecture by Kerboull [11]. The decision can be guided by the previously used approach to minimise damage to the soft tissues, most notably the abductor muscles. It is dependent on the reason for revision, components to be revised (femoral or both femoral and acetabular), and surgeon preferences. The possibility that a revision approach might prove necessary should be borne in mind and, therefore, approaches that are difficult to extend are best avoided.

3.2.1. Trochanteric osteotomy

The transtrochanteric approach offers excellent exposure of the acetabulum and access to the proximal femur, which can be worked on in alignment with its axis. Extracting a cemented stem is easily achieved after removal of the tissues and cement that cover the shoulder of the prosthesis. Expansion of this approach by creating a flap is fairly simple.

The challenge lies in the reconstruction and fixation of the greater trochanter, given the high risk of non-union. Many surgeons have discarded this approach.

3.2.2. Posterior approach

The simplicity and adaptability of the posterior approach have given it the place of prominence. During intramedullary stem removal, a prominent greater trochanter may limit the exposure of the intramedullary canal, thereby inducing a risk of cortex perforation or fracture. Another disadvantage is an increased risk of dislocation, which can however be considerably diminished by using a dual-mobility cup.

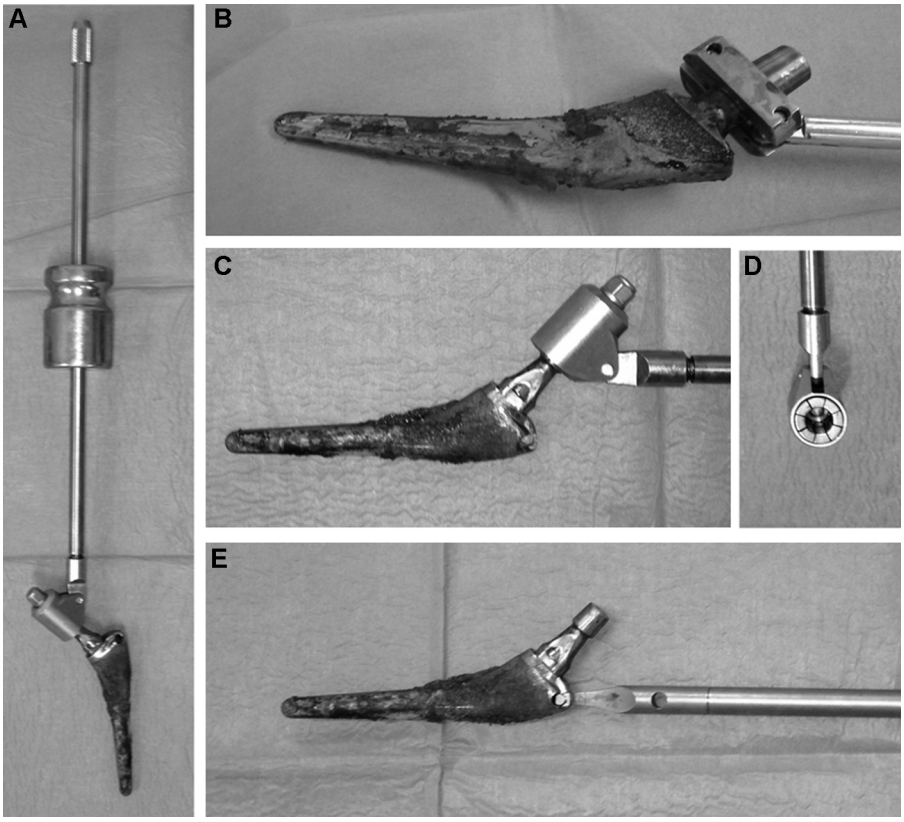

Fig. 2. Stem extraction instruments. Sliding hammer (A) mounted on a vise grip designed to encircle the neck (B) or a flaring system (C and D) or a hook (E) of use for stems with modular necks.

3.2.3. Other approaches

The anterior approach is chiefly attractive for primary arthroplasty. Considerable experience is needed to use it for removing a well-fixed femoral stem.

Anterolateral approaches require partial detachment of the gluteal muscles, whose strength is therefore diminished, increasing the risk of instability.

3.2.4. Extended approaches

When extraction of the stem is expected to be difficult, an extended approach with an ETO can be used from the outset, as discussed below.

3.3. Which ancillary instruments will be needed?

No single device is capable of extracting all stems. Specific extractors are fixed to the shoulder of the prosthesis, whereas generic extractors grasp the neck of the prosthesis (Fig. 2A–E). A modular neck constitutes an additional difficulty, as once it is removed, no site is left at which to apply the extracting device. Some prostheses have a small compartment with a threaded bottom at the base of the neck.

The full array of instruments designed for cement removal must be available:

- a range of chisels, both straight and curved, with various widths and lengths; gouges; and a flag splitter to break the cement mantle into fragments, with a set of flexible blades of variable lengths and widths (Fig. 3);
- hooks and curettes of variable sizes to extract the cement fragments and to look for a perforation of the cortex;
- drill bits and reamers of various diameters (Fig. 4A–H);
- saws with various blade sizes; a Gigli saw or reciprocating saw may prove useful;
- long pins (> 300 mm);
- trephines to remove fractured implants [12];
- tungsten drill bits, and metal-cutting saws or high-speed burrs.

A number of internal fixation materials must be at hand, including metal cerclage wires, plates for periprosthetic fractures, and trochanter hooks.

Considerable staff experience with hip revision surgery is crucial as changes in operated limb position, instruments and, in some cases, revision prosthesis type are often needed. The staff must be able to anticipate these changes and to implement them promptly.

3.4. Which type of revision prosthesis will be used?

Regardless of the type of implant considered, a long press-fit or locked stem should be available to ensure suitability for both the intramedullary and the transfemoral approaches and to allow re-implantation of a new prosthesis even in patients with intraoperative complications (fracture, cortex perforation).

Several options exist:

- cemented stem (standard or revision):
  - the transfemoral approach should not be used, as it precludes the delivery of cement under pressure, and leakage of the cement into the femoral osteotomy cuts would prevent bone healing,
  - it has been suggested that the new stem can be cemented into all or part of the previous cement mantle. No major

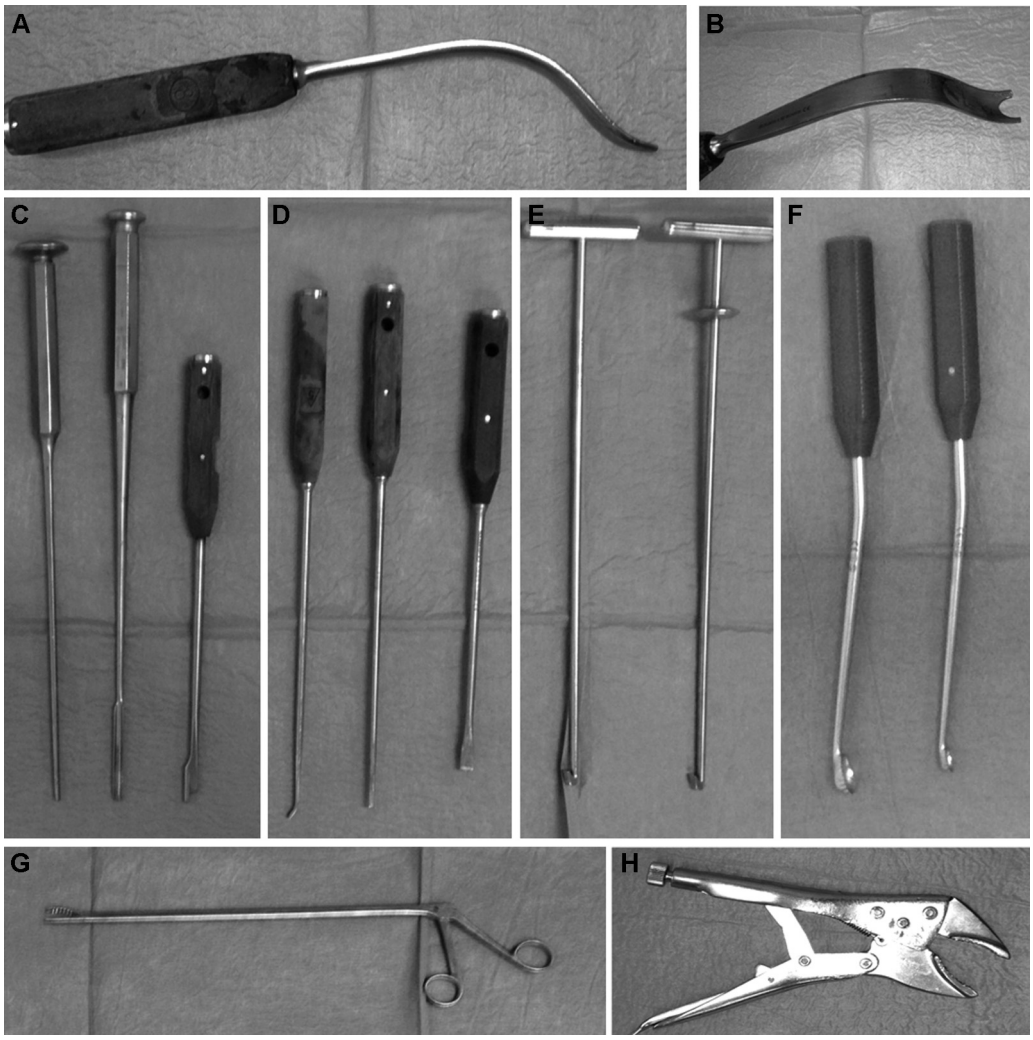

Fig. 3. Instruments of use for removing cemented implants and cement: recliner to expose the femur (A and B); chisels: straight, gouge, and flag for fragmenting the cement via the intramedullary canal (C); short straight and curved chisels to scape away the cement during close-up work (D); hooks (E) and curettes (F) for extracting the fragments up through the canal and palpating the walls of the canal; cement forceps (G); and self-locking universal vise grip (H).

complications have been reported with this technique [13,14]. The implant must be sufficiently small to fit inside the remainder of the mantle while allowing the introduction of a sufficiently thick layer of cement;

- cementless stem:
  - standard stem: the transfemoral approach (ETO or window) cannot be used,
  - revision stem: the length of the stem should allow distal anchoring of the stem in a healthy portion of the femur, taking into account any femoral curvatures (particularly in the sagittal plane),
  - locked revision stem: the wisest strategy is to create an ETO from the outset, as these prostheses must be adapted to the calibre of the femur; without an ETO, there is a risk of undersizing the implant, thereby preventing its osteo-integration.

3.5. Which extraction technique will be used?

Based on the analysis of the factors discussed above, the surgeon can decide whether to start by attempting axial retrograde extraction through the femoral canal. This method is usually successful and allows the re-implantation of a standard cemented or cementless stem.

3.5.1. Starting with an extended trochanteric osteotomy (ETO) is preferable in specific situations

- cemented stem:
  - proximal osteolysis with persistent distal fixation,

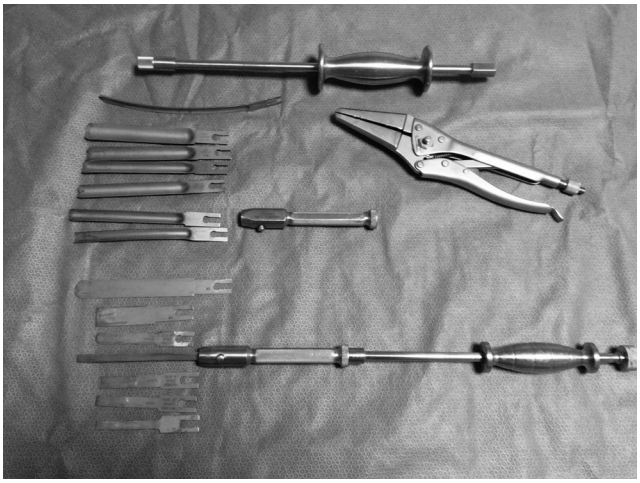

Fig. 4. Kit of flexible-blade osteotomes with an adjustable sliding bar.

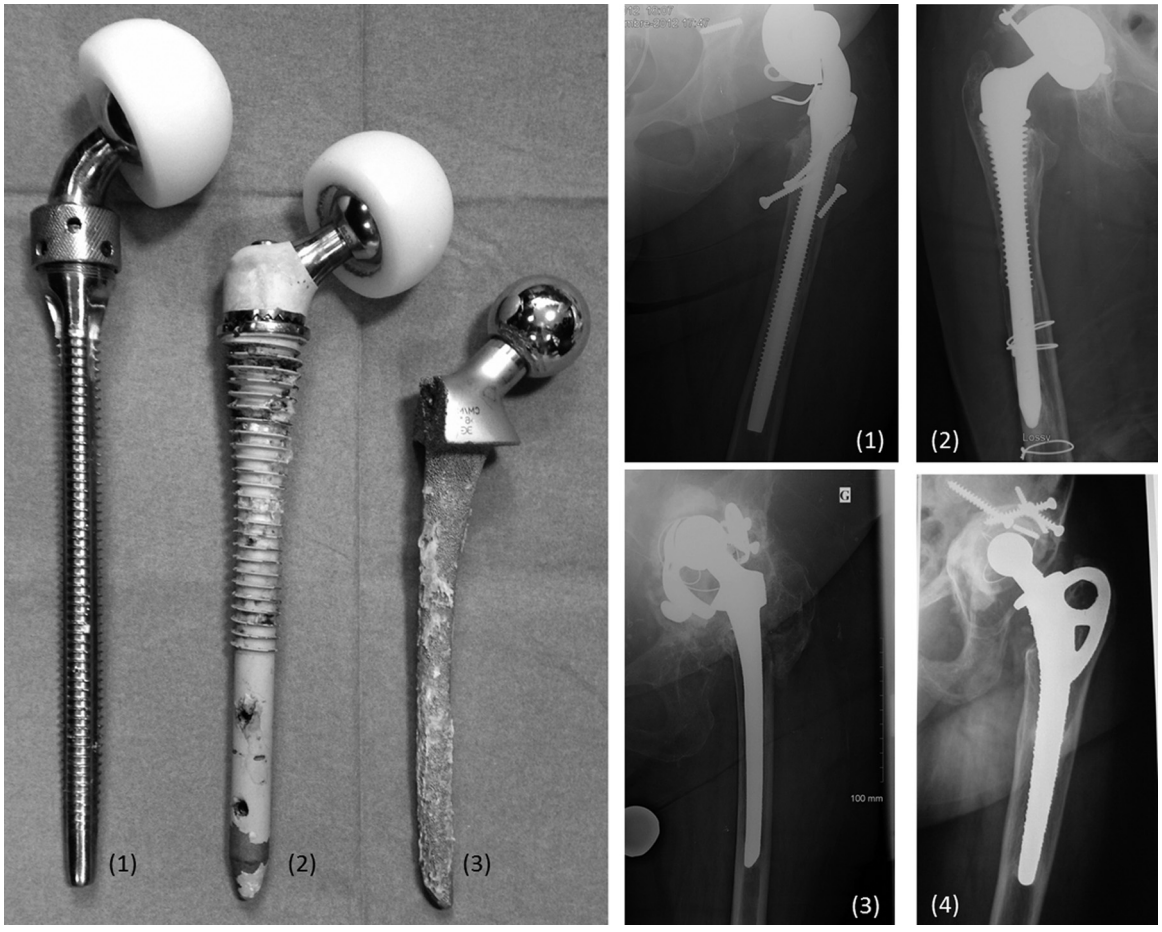

Fig. 5. Stems having the reputation of being non-removable: screw fixation (1 and 2) or porous metal or similar coating (3 and 4).

- long plug (> 30 mm), particularly if the stem is off centre;
- cementless stem:
  - fracture of the stem,
  - stem locked by screws or having a porous metal coating (Fig. 5),
  - long, fully coated stem,
  - extensive loss of diaphyseal bone,
  - mal-union or marked diaphyseal curvature;
- difficult or high-risk dislocation:
  - substantial ascension/medialisation of the cup,
  - marked subsidence of the stem,
  - large peri-articular ossifications or bony ankylosis,
  - particularly marked fragility of the greater trochanter and/or of the femur;
- revisions for chronic infection.

The ETO should be planned carefully [15]. A single, pedicled, well-vascularised flap is preferable over several devascularised fragments, which will fail to heal and may even undergo resorption.

The length of the flap is determined based on the characteristics of the stem to be removed (Fig. 6A–D):

- cementless stem:
  - with a macroporous coating: the flap should be as long as the stem,
  - with a microporous coating on its entire surface: the flap can be 3–4 cm shorter than the stem,
  - with a microporous coating on part of its surface: the flap is sized based on the coated portion;
- cemented stem.

A flap that ends 2–3 cm proximal to the tip of the plug allows safe extraction of the plug (unless the plug is longer than 3 cm).

The intraoperative landmarks are the apex of the greater trochanter, the lesser trochanter, or landmarks on the prosthesis (e.g., centre of the head, shoulder).

In all other situations, the worst-case scenario should be anticipated: intramedullary extraction is attempted first, but plans for an extended approach are made.

3.5.2. The patient should be fully informed of these difficulties

The risk/benefit ratio should be discussed and explanations given about the various bone cuts that might be needed (e.g., osteotomy, femoral osteotomy, trochanteric osteotomy). These points should also be discussed with the anaesthesiologist.

4. Extraction technique

4.1. Extraction of a cemented stem through the intramedullary canal

4.1.1. Extraction of the stem

Any material built up at the shoulder of the prosthesis (soft tissue, bone, cement) that might hinder extraction of the stem should be removed to minimise the risk of fragilising or fracturing the greater trochanter.

Dislocation of the prosthetic joint is often readily achieved. Care should be taken not to perform forceful manoeuvres, which might fracture the femur or greater trochanter. Dislocation may be

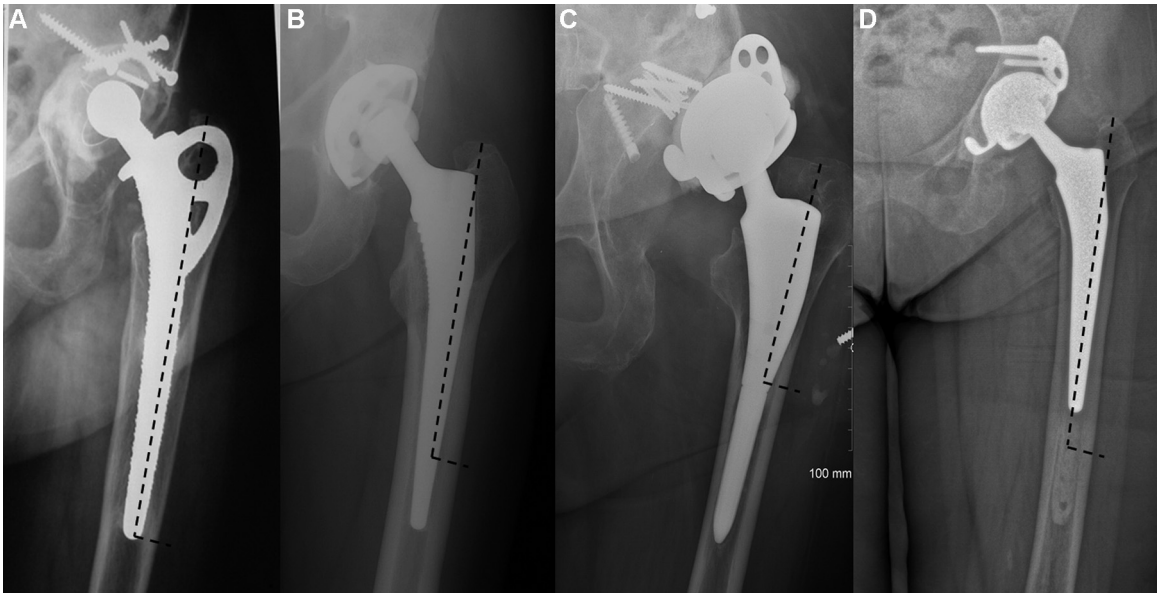

Fig. 6. Planning the length of the flap. Stems with a porous metal coating (A), microporous coating (B), or partial coating (C). Cemented stem with a long cement plug (> 30 mm).

difficult to obtain despite soft-tissue release. This scenario requires an ETO, which is associated with less morbidity than a fracture.

A broad laminar spreader is used to exteriorise the proximal femur (Fig. 3A, B). The spreader is applied under the calcar to align with the axis of the femur, thereby obviating the need for forceful manoeuvres.

The stem is easily removed in most cases, particularly if it is smooth. A rough cemented stem may raise problems similar to those seen with a cementless osteo-integrated stem.

The main challenge resides in removing the cement and plug [4,16]. Complications include perforations, fractures, and incomplete cement removal responsible for further bone damage that may compromise the implantation of the new femoral component [3,6].

4.1.2. Removal of the cement

The surgeon should move methodically from proximal to distal and from posterior to anterior. Slender straight cement chisels should be used with caution, with the blade pointed towards the cement to avoid bone damage. A cerclage wire placed under the lesser trochanter is useful in preventing a fracture. Perforations, however, occur more distally. Visual control should be maintained at all times, if needed, using a lavage, aspiration, and lighting system.

The cement mantle should be split longitudinally to allow the extraction of large cement fragments (Fig. 7).

Hooks and curettes serve to probe the canal and to palpate the walls while extracting the fragments. A reaming guide is used to determine the site of the plug.

A tunnel is then drilled through the exact centre of the plug (Fig. 8). A drill bit measuring 8/9 mm in diameter is appropriate, although a slightly larger bit may be useful, as a small diameter increases the risk of perforation. This step is easy to perform if the plug is short (15–20 mm) and the stem centred. A plug longer than 30 mm and/or an off-centre stem are complicating factors. The recovery of fragments from a polyethylene obturator is a good sign.

Several surgical devices have been suggested:

- intracanal [17] or peridiaphyseal [16] aiming systems for reaming the femur;
- ultrasound application to heat the cement, thereby causing it to disintegrate. Slow gradual progression is crucial [18]. This

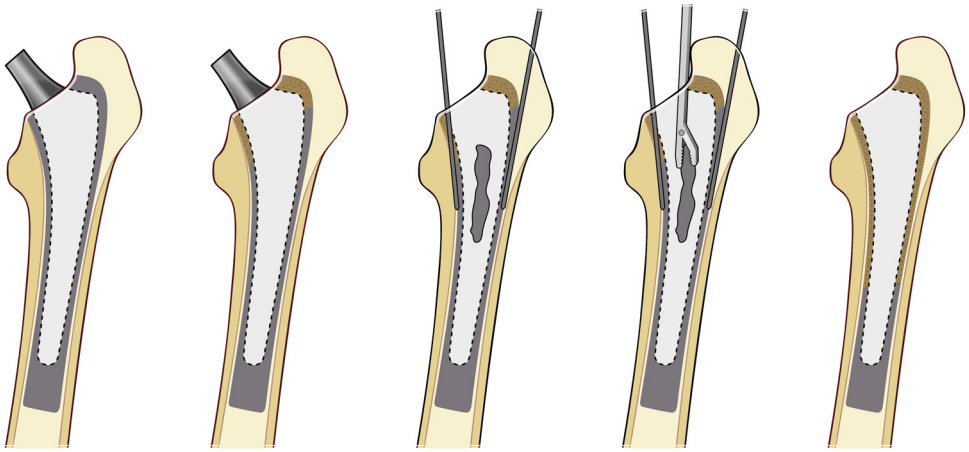

Fig. 7. The cement should be removed gradually and methodically from proximal to distal.

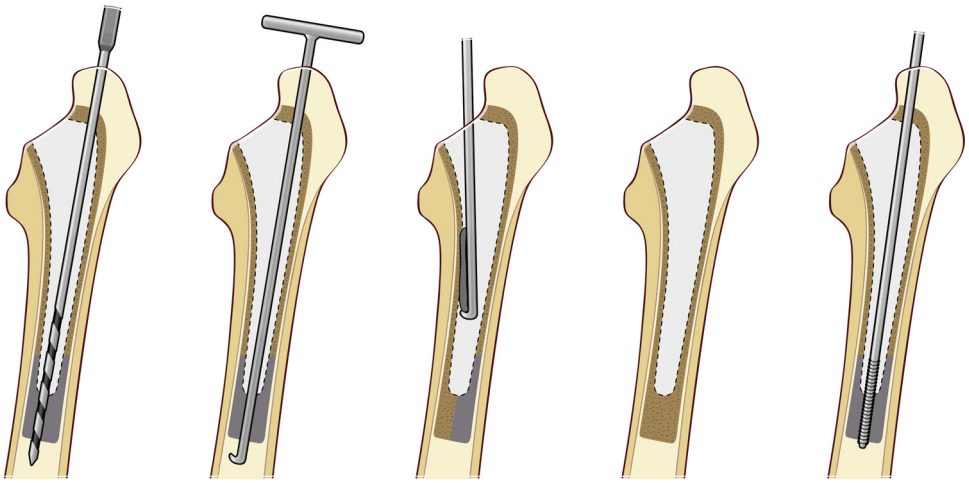

Fig. 8. A hole is drilled through the plug to allow the passage of a hook. Alternatively, a tap can be used.

method obviates the need for an ETO or allows a reduction in its length and permits preservation of the isthmus in patients with a long plug [19];
- motors characterised by a very high rotational speed (Cebotome™, Conmed Linvatec Hall) can fragment the cement but should be used with caution;
- the Segmental Cement Extraction System (Seg-Ces™) is composed of nuts mounted on a threaded rod, which is cemented into the cement mantle; the rod, nuts, and cement are then extracted as a single unit [20].

After a hole is made in the plug, a long, slender, flexible reaming guide is introduced into the femur. A sensation of bony contact at the distal femur is an auspicious sign, whereas a sensation of contact with soft tissue may indicate a perforation, which must be approached.

The guide serves to introduce powered reamers of increasing size, which may be either rigid or, if the femur is curved, flexible. A retrograde hook (or a tap) is used to go beyond the plug, which is then removed. As cement is harder than bone, the presence of a residual cement fragment can result in eccentric reaming with thinning of the cortex or even a perforation or a fracture. At the slightest doubt, fluoroscopy with an image intensifier should be used to obtain anteroposterior and lateral views of the progression of the reamers. The plug may be pushed to a more distal position, where it can be left if it does not hinder the implantation of the new stem. However, if infection is the reason for revision, leaving the plug is not desirable. The safest course of action consists in obtaining a radiograph then, should removal of the plug prove indispensable, creating a window.

When the cement and particularly the plug cannot be removed, the creation of a cortical window has been advocated [21] (Fig. 9). The following rules must be followed:

- the window should be positioned optimally, under fluoroscopic guidance, in order to overlap the distal tip of the plug by 1–2 cm;
- the length of the window should be 3–4 cm and its width smaller than one-quarter of the femoral circumference;
- the long axis of the window should be superimposed over the long axis of the femur;
- the window angles should be rounded and marked using a 2.7-mm drill bit;
- a cerclage wire should be placed immediately distal to the window;
- the new stem must bridge the window over a distance at least equal to its length [4].

Every effort should be made to avoid having to create a window, which increases the risk of fracture. An ETO is preferable, as it provides full exposure and is associated with an excellent likelihood of healing.

Trochanteric osteotomy is not recommended in this situation, except in patients with non-union of the trochanter, which should be put to good use. In this case, osteolysis responsible for increased fragility of the greater trochanter is common. An additional flap should not be created, as it would worsen the bone damage.

4.2. Extraction of a well-fixed cementless stem through the intramedullary canal

The joint should be dislocated, the tissue growing over the shoulder of the prosthesis excised, and the calcar exposed to allow passage of the chisels.

The objective is to disrupt all the bone connections between the femur and stem (Fig. 10). Thin, short, wide chisels with flexible blades are used first. They are slipped along the anterior and

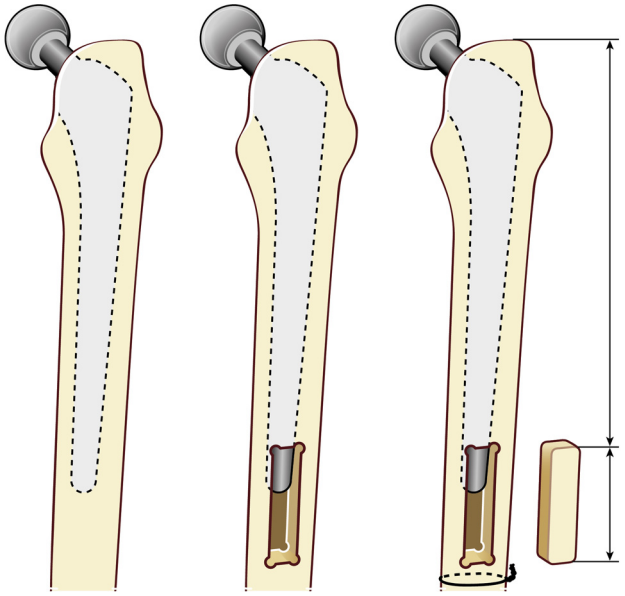

Fig. 9. Femoral window with a distal cerclage wire.

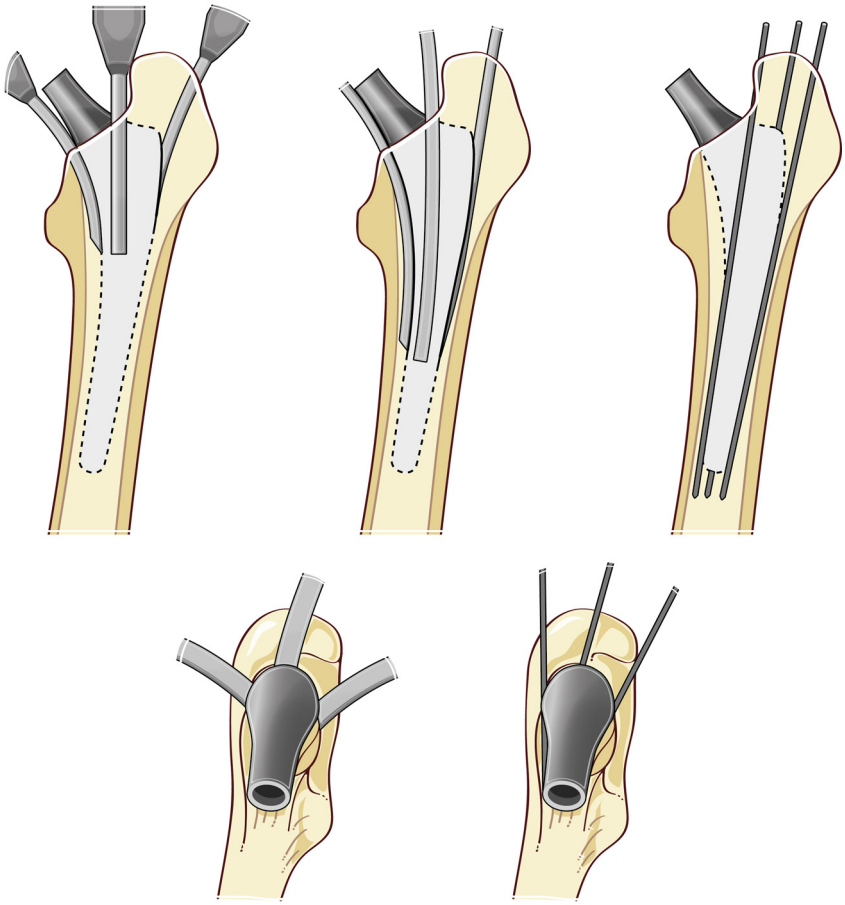

Fig. 10. Extraction of a cementless stem via the intramedullary canal. Slender chisels then pins are introduced to disrupt the bone connections.

posterior aspects of the stem, with the bevel towards the implant. The chisels should be introduced cautiously and, above all, removed without performing any inopportune extraction manoeuvres. The lateral and medial aspects of the implant are then cleared using narrower blades. If the calcar is fragile, a cerclage wire can be passed around it to prevent a fracture.

As one progresses towards the distal tip of the stem, longer and narrower chisels are used. To disrupt the distal bony connections, pins placed on power are driven along the various aspects of the stem, with special attention to the sensation indicating their passage beyond the distal anchoring point.

After clearing all the aspects of the implant, a few impaction and extraction manoeuvres are performed in alternation to disrupt the last bony connections. The stem is then removed, using an appropriate extraction system if one is available. Otherwise, a universal vise grip can be placed around the neck then tapped with a mallet.

If this method fails, the zones that remain fixed must be accurately localised. Above all, a pedestal should be sought. A pedestal is extremely difficult to access through the intramedullary canal, particularly when the stem has an anatomic curvature.

A reasonable time for attempting the extraction is 30 to 45 minutes. If the extraction fails, a femoral osteotomy should be performed.

4.3. Extraction via an extended approach after failed intramedullary extraction

4.3.1. Femoral osteotomy

The hip is reduced after repositioning the femoral head to avoid damaging the cup. The incision is extended distally, the fascia lata is opened, and the vastus lateralis is reclined. If needed to improve visibility of the femur, the linea aspera can be exposed by dividing the gluteus maximus 1 cm from the bone, to allow for subsequent reattachment. The insertions of the vastus are left intact to preserve the blood supply to the femur and the continuity of the gluteus medius-greater trochanter-vastus lateralis chain, which functions as a digastric muscle.

The contours of the femoral osteotomy are marked according to the pre-specified plan, by creating a row of holes using 2.7-mm drill bits. A cerclage wire is placed distally to prevent fracturing. An oscillating saw is used to perform the bone cut at the lateral aspect of the femur, midway between the linea aspera and the anterior edge, to allow conversion to an ETO if needed.

The elasticity of the bone is taken advantage of with caution, by using slender chisels to displace the cortex away from the stem (Fig. 11A and B). However, access to the anterior and anteromedial aspects is limited. A new attempt to remove the stem using an extraction system can be made.

If this attempt fails, it is important to check that the femoral osteotomy is sufficiently long. It can be extended if needed, provided an at least 4-cm segment of the isthmus is spared [12]. If the osteotomy is sufficiently long or if extending, it would threaten the integrity of the isthmus, a second femoral osteotomy can be performed (creating a bony strut). The second cut is parallel to the first, located more anteriorly and at a distance of at least 15–20 mm to minimise the risk of fracture at the distal portion or, worse, at another site, as this would create small devascularised bone fragments. However, conversion to an ETO is a better option.

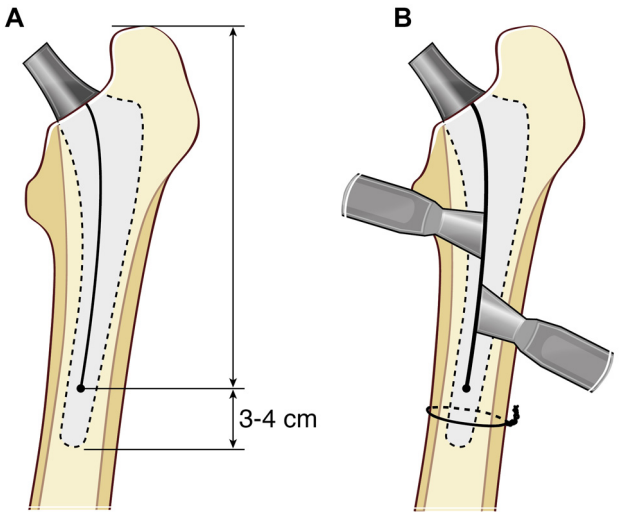

Fig. 11. A. Planning the femoral osteotomy, which spares the last 3–4 cm. B. Stem extraction after placement of a cerclage wire.

4.3.2. Extended trochanteric osteotomy (ETO) (Fig. 12)

This approach can be used either after failure of direct intramedullary extraction of a cemented or cementless stem or of a cement plug, or after a femoral osteotomy to extract a cementless stem.

It must be planned in advance, at the time of the initial femoral osteotomy, which serves as the posterior cut.

Two holes are drilled to serve as markers for the distal cut. The femur is exposed over a few centimetres around this zone to allow the placement of a distal cerclage wire.

The anterior cut is performed with the lower limb in external rotation, in two steps to preserve the blood supply to the detached fragment. On the distal half, the vastus lateralis is elevated and the osteotomy performed using an oscillating saw. Proximally, the interval separating the gluteus medius and proximal vastus lateralis from the osteotomy is released using either a broad osteotome or a saw, from anterior to posterior, under visual control. Another useful device consists in drilling a row of small holes to fragilise the anterior cortex along the flap contour, if needed with the help of a drill guide, through the vastus lateralis, which is thus preserved. Another suggested technique involves perforating the anterior cortex using pins introduced through the posterior osteotomy; however, as the pins are displaced lateral to the stem, the resulting flap may be too narrow.

The detached fragment, which is often adherent in the trochanteric region, should be lifted cautiously by introducing two or three broad osteotomes through the posterior cut. Care should be taken to avoid causing a fracture, particularly in the subtrochanteric area. The detached fragment is displaced anteriorly and maintained in the appropriate position by double-angled retractors slipped under its intramedullary aspect and applied on the diaphysis. The femoral stem is exposed and released down to its distal tip using the same instruments as for intramedullary extraction. For stems with advanced osteo-integration, a reciprocating saw or Gigli saw can be slipped between the bone and the stem starting at the calcar; this method is difficult to use, however, with fluted stems, which cause frequent blocking of the saw. If stem exposure is incomplete, its distal attachments to the femoral bone must be disrupted using slender bone chisels or pins. Once the stem is fully exposed, the hip is dislocated and the implant removed by using an extractor or applying a mallet to a flange.

If the detached fragment is too short to allow stem extraction using these manoeuvres, an intraoperative radiograph should be obtained to determine the reason for failure (e.g., pedestal). Extending the ETO detaches a cortical fragment devoid of any blood supply and is therefore best avoided. A better option is a window at a distance, with a sufficiently large bony bridge. When creating this window, the previously mentioned rules should be followed: the window should overlap the tip of the stem over 1 to 2 cm. Alternatively, the stem can be cut at the level of the transverse cut of the flap and its distal portion extracted using a slightly oversized trephine [12], provided this possibility was anticipated and the necessary equipment made available.

A window distal to an ETO can be a good option when a long stem is well fixed (as occurs with modular revision stems fractured at the metaphyseal-diaphyseal junction) and a very long ETO is not feasible because it would compromise the integrity of the isthmus.

For cemented stems, once the flap is created, the stem is fully exposed and the cement can be completely removed while working along the axis of the femur, with no risk of perforation during drilling and removal of the plug (Fig. 13). Several points deserve to be emphasised:

- cutting the bone and lifting the detached fragment are easier to perform after removal of the stem; in particular, the anterior cortex can then be cut directly through the posterior cut;
- the flap should be sufficiently long to allow complete removal of the cement, but at least 4 cm of the isthmus must be preserved;
- in the event of a very long plug, the best plan consists in creating a shorter ETO combined with one or two distal windows under radiographic guidance; a revision implant that extends

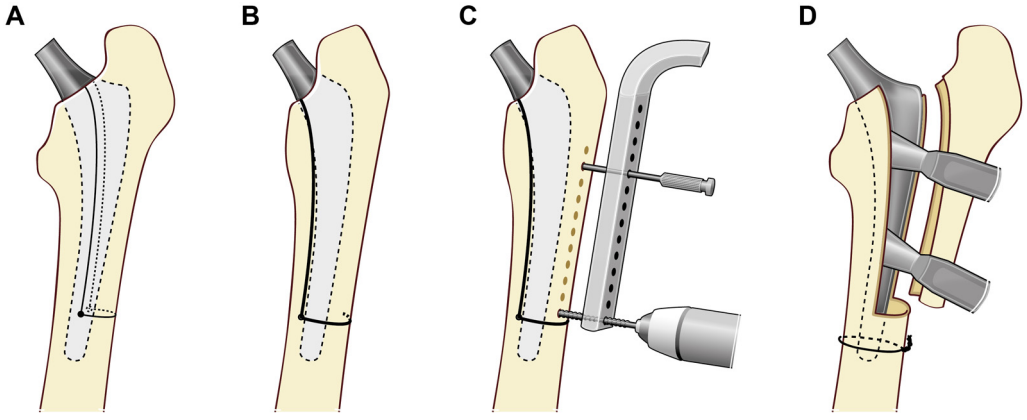

Fig. 12. Planning and creating a femoral flap. A. A 2.7-mm drill bit is used to mark the cutting lines. B. The transverse cut is made first and the posterior cut second. C. The anterior cutting line can be marked by drilling a row of holes. D. Chisels are used to gently lift the flap.

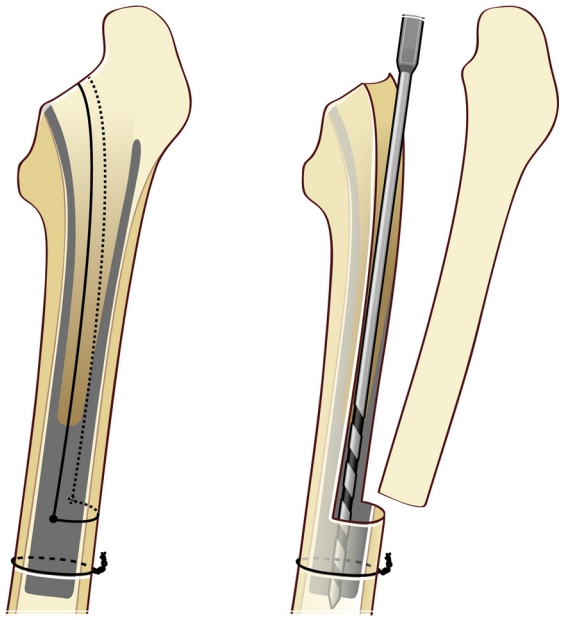

Fig. 13. Perforation then extraction of the cement plug after creation of a femoral flap.

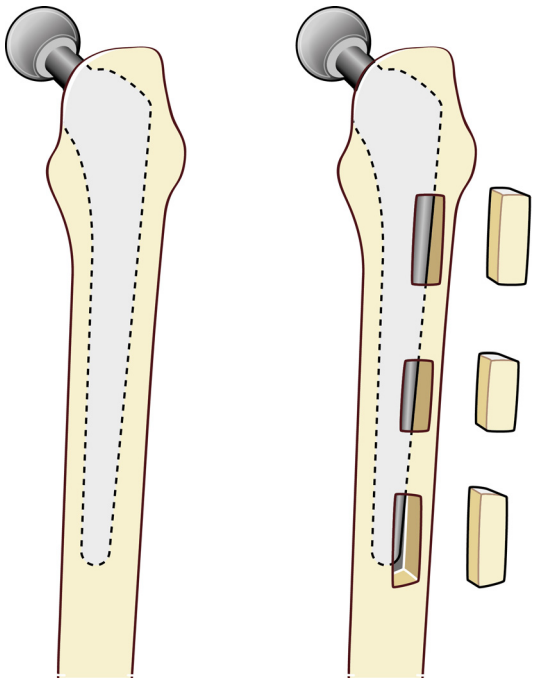

Fig. 14. The sarcophagus approach developed by Doré (series of windows) to preserve the continuity of the lateral cortex.

sufficiently beyond the window or windows must be available. In this situation, ultrasonography is extremely useful to avoid having to create distal windows.

4.4. Primary extraction via an extended approach

4.4.1. Primary ETO

The planned ETO length is marked on the diaphysis based on bony or prosthetic landmarks. The ETO is created without any posterior release and without dislocating or removing the implant. This method spares the posterior soft tissues (particularly the lateral rotators of the hip and the gluteus maximus), thereby decreasing the risk of postoperative dislocation.

The position of the posterior osteotomy is slightly more anterior than described above. The challenge then consists in performing the anterior osteotomy, particularly when there is marked stiffness of the hip with a limited range of external rotation, and subsequently in lifting the detached fragment.

In the following situations, a primary ETO is not sufficient.

4.4.1.1. Curved femur. To allow implantation of the revision stem, a re-orientation osteotomy must be performed. When planned carefully, this osteotomy can facilitate stem removal. However, it is best performed after extracting the stem and before implanting the revision stem. This osteotomy serves to re-align the proximal medial femur on the stem, to close the femur, and to bring the femur in contact with the prosthesis.

4.4.1.2. Fractured stem. The stem may be fractured at various sites:

- at the femoral neck;
- at the junction of a modular neck with the stem;
- at the junction between the proximal non-osteo-integrated portion and the distal osteo-integrated portion of the stem (e.g., at the metaphyseal-diaphyseal junction of modular revision implants).

In this situation, no system is available for extracting a well-fixed stem. A primary femoral osteotomy or ETO is required. For very long revision stems, either a window combined with a long ETO or trephines can be used.

4.4.2. Variants

The transfemoral approach described by Vives and Picault [22] follows the principles of extended approaches. It consists in an anterolateral ETO similar to that described above, with two flaps (the "three-thirds technique", with a posterior flap and an anterolateral flap), or three flaps (the "four quarters technique"). The linea aspera is decorticated to improve exposure and, above all, to stimulate bone healing.

The "sarcophagus" technique developed by Paumier and Doré [21] consists in cutting a series of windows in the lateral aspect of the femur to preserve the continuity of the cortex while providing access to the intramedullary cavity (Fig. 14). The stem is released by progressing from one window to the next. The windows are created as needed during the stepwise extraction of the stem and/or cement.

5. Complications

5.1. Perforation

Simple perforation has only limited consequences if a long stem extending at least 5 cm beyond the bony defect can be implanted. Otherwise, internal fixation is needed to prevent a fracture.

A perforation discovered intraoperatively should be approached, and the femur protected by a cerclage wire. This procedure can be taken advantage of to extract the stem and/or cement. If the amount of residual cement is considerable or the femur fragile, an ETO can be created. The length of the ETO should be determined based on the location of the bone injury. A posterior or posterolateral injury can serve as the transverse cut of an ETO. If the injury is anterior or anteromedial, the transverse cut of the ETO should be made at a safe distance of two diameters from the injury whenever possible.

5.2. Fracture

A periprosthetic fracture can be used to create an ETO.

If a fracture occurs under the prosthesis, an ETO can be created along the entire height of the femur above the fracture, provided there is no danger of damage to the isthmus. Otherwise, the fracture must be reduced and fixed using cerclage wires or a locking screw plate with unicortical screws opposite the new stem [23].

5.3. Fracture of the greater trochanter

If the greater trochanter becomes fractured during the creation of an ETO or dislocation of the hip, this procedure must be stopped immediately to limit the displacement and to preserve the continuity of the gluteus medius-greater trochanter-vastus lateralis chain. The fracture should be reduced and fixed using two or three pins, starting at the apex of the greater trochanter and penetrating the lateral cortex.

The use of a plate to close the femur is not recommended, as this method damages the blood supply to the bone, thereby compromises the chances of healing. Instead, cerclage wires should be passed around the greater trochanter and one or two long screws implanted through the apex of the greater trochanter and behind the stem, until they rest on the lesser trochanter. Factors that complicate this procedure are the bulk of the prosthetic metaphysis and the quality of the bone.

In every case, special care should be taken during internal fixation to ensure good contact with the bone and strong fixation.

5.4. Failed stem extraction

The head or modular components of the prosthesis should be kept under fully sterile conditions to allow completion of the surgical procedure should extraction of the stem prove impossible. This situation is probably among the most serious, as the implants damaged by the extraction attempts must be re-used, and the patient is exposed to the complications of major surgery (e.g., infection and bleeding).

6. Conclusion

Extraction of a well-fixed stem can be challenging, and plans must be made for this possibility. Thorough familiarity with the stem to be removed, together with a meticulous analysis of a comprehensive set of recent radiographs, allows the implementation of measures capable of preventing many difficulties.

In our experience, the posterior approach should be preferred if the stem is well fixed, as it allows the management of all situations, including perforations and fractures. In the absence of infection, the stem can often be removed through the intramedullary canal provided stringent technique is followed by an experienced and patient surgeon.

Routine use of an extended approach is open to criticism, but exaggerated optimism is equally unhelpful. The worst-case scenario should be anticipated. In particular, the required instruments and implants should be available in the event of an intraoperative decision to perform an extended approach followed by reconstruction. Thus, intramedullary extraction can be undertaken only after planning for more complex procedures. In some cases, a well-sized ETO must be created from the outset. When performed properly, this approach is associated with less morbidity compared to unmanaged or poorly managed complications.

In sum, extraction of a well-fixed stem requires familiarity and expertise with all three possible techniques:

- extraction of a cementless stem through the intramedullary canal;
- extraction of a cemented stem and its cement mantle and plug through the intramedullary canal;
- extraction of a stem through a femoral flap.

Disclosure of interest

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