Trochanteric slide osteotomy in revision total hip arthroplasty for loosening

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We used a trochanteric slide osteotomy (TSO) in 94 consecutive revision total hip arthroplasties (90 with replacement of both the cup and stem). This technique proved to be adequate for removing the components, with few complications (two minor fractures), and for implanting acetabular allografts (18%) and reinforcement devices (23%). Trochanteric union was obtained in most patients (96%), even in those with septic loosening (18/19), major femoral osteolysis (32/32), or previous trochanteric osteotomy (17/18). TSO is versatile, since it can be extended by a femoral flap (four cases) or a distal femoral window (eight cases). Despite significant bone loss, in 24% of the femora and 57% of the acetabula, favourable midterm results were achieved and only six reoperations were required, including two for trochanteric nonunion and two for loosening. It leaves the lateral femoral cortex intact so that a stem longer than 200 mm was needed in only 25% of patients. This is a considerable advantage compared with the extended trochanteric osteotomy in which the long lateral flap (12 to 14 cm) requires an average length of stem of 220 mm beyond the calcar.

TSO provides an approach similar in size to the standard trochanteric osteotomy but with a rate of nonunion of 4% versus 15%. It reduces the risk of difficulties with removal of the stem, and removes the need for routine distal anchoring of long revision stems. The limited distal femoral compromise is very important in patients with a long life expectancy.

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Revision for loosening in total hip arthroplasty (THA) can be performed through extended posterior or anterior approaches which preserve the continuity of the abductor mechanism, but may fail to provide sufficient acetabular exposure for the reconstruction of large bony defects.

Trochanteric osteotomy provides ample exposure for acetabular reconstruction and facilitates removal of the stem and reconstruction of the femur. In this setting, however, standard trochanteric osteotomy is associated with a high rate of nonunion which can cause instability and shorten the survival of the prosthesis. Wider approaches can be used, such as the extended trochanteric osteotomy, which runs distally along 12 to 14 cm of the lateral metaphyseal and upper diaphyseal cortex, or the transfemoral approach which extends to the tip of the prosthesis. These techniques provide excellent exposure of the femur and acetabulum but require distal anchoring with a long femoral stem, which further compromises the femur. This prompted us to use a trochanteric slide osteotomy (TSO) in a series of revision THAs of intermediate difficulty. Our aims in this review were to determine: 1) whether the rate of union of the osteotomy and strength of the abductor muscles after operation were satisfactory; 2) whether the absence of a distal osteotomy of the lateral femoral metaphysis allowed a short femoral stem to be used in most patients; and 3) whether the exposure offered by TSO was sufficiently wide to avoid complications during removal of the prosthetic components and to allow reconstruction of the acetabulum and femur.

Patients and Methods

We studied 94 consecutive patients with loosening of a THA who had undergone revision using a TSO between 1993 and 2000. The loosening was aseptic in 75 and septic in 19. There were 61 cemented arthroplasties (with cement for both the cup and the stem), 21 hybrid arthroplasties (with an uncemented cup), and 12 uncemented arthroplasties. Thus, 82 stems were cemented (35 Müller, 25 Charnley, and 22 others) and 12 were uncemented (four fully porous-coated and eight with porous ingrowth or hydroxyapatite coating), and 61 cups were cemented and 33 uncemented. These prostheses had been manufactured by nine different companies; 89 patients had been referred from other centres, and five had been previously operated on in our department.

Fig. 1a

Fig. 1b

Fig. 1c

Fig. 1d

Diagrams showing TSO. Fig 1a – Minor elevation of vastus lateralis and osteotomy in a posterior to anterior direction. Fig. 1b – The hip is slightly flexed and the trochanter rotates around the anterior osteotomy line. The dissection preserves the anterior vascularisation of the trochanter. Figures 1c and 1d – Fixation is aimed to avoid upward migration and to prevent tilting in the sagittal plane. Prevention of tilting is achieved proximally by one wire (arrow 1) in the axial plane and distally (arrow 2) by vertical wires passing through a trochanteric notch.

Fig. 2a

Fig. 2b

Fig. 2c

Radiographs showing that TSO can be extended by a window or a flap. Figures 2a and 2b – A window can be used to remove the cement plug. In standard cases the stem can extend only 2 cm distally to the window. In this patient there was a satisfactory result at follow-up at six years. Fig. 2c – A femoral flap was used in this patient with a fully porous-coated prosthesis. There was loosening of the cup on the left side and proximal femoral osteolysis. The preserved vascularisation of the trochanter and flap allowed fusion. Osteotomy lines (arrows) are barely discernible at two years follow-up.

A Charnley-type prosthesis was implanted for revision in 86 patients. A hydroxyapatite-coated long stem with distal interlocking screws was used in six patients and impaction grafting in two.

Both prosthetic components were changed in 90 patients. In 36 of these, both components were loose and in 16 one component was loose and the other had severe associated osteolysis. In 38 patients, one component was loose and the other had moderate or no associated osteolysis but was changed because of inadequate positioning, wear exceeding 2 mm, or poor design (head diameter 32 mm, polyethylene thickness ≤ 7 mm or an oversized neck which allowed impingement). Only the stem was changed in four patients.

Operative technique. Figure 1 illustrates the technique of TSO. A posterolateral approach is used with blunt dissection of gluteus maximus, identification of the underlying muscles, detachment of vastus lateralis along approximately 3 to 4 cm below the trochanteric ridge, and identification of the posterior edge of gluteus medius. TSO is performed in a posterior-to-anterior direction using an oscillating saw. Distally, the cut usually ends 6 cm below the tip of the greater trochanter. The cut is flush with the lateral edge of the upper aspect of the implant which is being revised. Anteriorly, it ends at the medial edge of gluteus minimus, so that the blood supply from this muscle to the anterior trochanter is left intact. The hip is flexed, so that the trochanteric fragment is displaced forwards, allowing the surgeon to release the anterior soft tissues flush with the anterior edge of the femoral neck in order to preserve the anterior blood supply to the trochanter. At the end of the procedure, three vertical cerclage wires are placed in the coronal plane to prevent

upward migration of the trochanter. In order to prevent tilting of the trochanter in the anteroposterior direction during flexion and extension of the hip, the upper third of the greater trochanter is secured with a cerclage wire placed in the transverse plane and passing through the lesser trochanter. In addition, the vertical wires are passed through a notch cut in the lower part of the greater trochanter.

During the early postoperative period, the patient uses crutches with partial weight-bearing of approximately 20 kg. Passive exercises and isometric contractions of the gluteal muscles are performed. Full weight-bearing is started at six weeks with the use of a crutch for the first month.

We used extensions of this technique in 12 patients (Fig. 2). In eight, vastus lateralis was detached and a femoral window was cut to remove adherent distal cement or the entire plug. In four patients, the transfemoral approach was used to remove a fully porous-coated prosthesis which could not be removed using TSO alone. A saw was used to cut the bone, first immediately anterior to the linea aspera, then hemicircumferentially at the lower edge of the first cut. Two small vertical cuts about 15 mm in length at the medial edges of the proximal and distal parts of the osteotomy defined the medial hinge. Most of the femoral attachments of vastus lateralis were preserved. Multiple cerclage wires were used for closure.

Evaluation criteria. Clinical classification was according to the Merle d'Aubigné score based on pain, movement and walking ability. Overall abductor strength was scored on a scale of 0 to 5 (3, resists gravity; 4, good resistance but tires; 5, normal resistance). The stability of single-leg stance on the affected side was compared with that on the unaffected

Fig. 3

Diagrams showing the relationship between the type of osteotomy and the length of the revision stem. Fig. 3A – This shows a loose stem. The mean femoral compromise is 14 cm distal to the calcar (18 cm below the tip of the greater trochanter). If the tip of the revision stem (or cement) is more than 20 cm below the calcar, the femoral compromise is considered to be major. Fig. 3B – In TSO, the osteotomy line is 5 cm below the tip of the greater trochanter. In 75% of cases, the tip of the revision stem (or cement) is less than 20 cm below the calcar, with minor femoral compromise. Fig. 3C – In extended TSO the line is 12 cm to 14 cm distal to the tip of the greater trochanter. The mean by-pass of the stem is 14 cm. The mean femoral compromise is 27 cm below the tip of the greater trochanter (23 cm below the level of the calcar). Fig. 3D – In the transfemoral approach, the tip of the stem is often 26 cm distal to the calcar.

side. Radiological assessment of acetabular bone loss was based on the criteria of the American Academy of Orthopaedic Surgeons (AAOS). For the femur, we used the SOFCOT classification:^{1,2} stage 1 is minimal osteolysis mainly in the calcar, stage 2 includes moderate lateral osteolysis, stage 3 is severe osteolysis with marked thinning of the lateral cortex, and stage 4 major medial and lateral cortical thinning along the entire length of the prosthesis. Union of the trochanteric osteotomy was rated using a four-grade system.

The objective of femoral revision is to achieve long-lasting fixation of the femoral component with a short femoral stem in order to avoid further compromise of the diaphyseal bone stock. We therefore measured the length of femoral compromise, which is the distance between the calcar and the distal end of the cement plug (Fig. 3). After insertion of a primary prosthesis, the length of femoral compromise is about 14 cm (e.g. for a cemented plug component, 12 cm for the stem and 2 cm for the cement). We defined major femoral compromise as a calcar-to-tip-of-stem (or cement) distance of greater than 20 cm after the revision. Minor femoral compromise was defined as a calcar-to-tip distance of 20 cm or less, usually indicating that the stem length was 18 cm.

Results

Trochanteric union. The overall rate of nonunion was very low (4/94 hips, 4.2%). Only two patients with nonunion required further surgery.

In situ union (type A) occurred in 78 patients (83%). This was documented at one year for 76 hips and at three months for two hips which were not re-evaluated at one year. In seven patients, union occurred after proximal migration of the fragment (type B) by a mean of 8 mm (3 to 12), with an abductor strength score of $\geq 4/5$. Five patients had heterogeneous callus (type C) but without continuous fibrous interposition between the trochanter and the metaphysis. No proximal migration of the trochanter was noted during follow-up of between one and five years. The abductor strength score was $\geq 4/5$.

Nonunion with a gap greater than 5 mm (type D) occurred in four patients. Two had supported their full weight on the operated limb immediately after surgery. One was an obese patient (100 kg) who had misunderstood the postoperative instructions and the other had a bony defect of 6 cm in the contralateral femur which precluded limitation of weight-bearing. The other two patients had no major risk factors for nonunion. Of these four patients with a type-D nonunion, two required further surgery for prosthetic instability. The remaining two patients were older than 50 years of age and had an abductor strength score of 4/5. Further surgery was therefore not needed.

In situ healing occurred in 18 of the 19 patients with septic loosening. The remaining patient had heterogeneous callus. Marked lateral femoral osteolysis (stage 3 or 4) was seen in 23 patients, of whom none had nonunion and only two had heterogeneous callus. In 18 patients, the revised prosthesis had been implanted through a trochanteric osteotomy. Nonunion developed in one of these

repeated trochanteric osteotomies and two had heterogeneous callus.

Removal of components. The wide approach of the TSO allowed removal of the stem and cement, even in the substantial group of patients whose distal stem was firmly embedded in cement. There were only two perforations, neither of which had adverse consequences. Windows to remove the distal cement or the plug were needed in only six cases. Of the 12 stems with porous ingrowth, six were successfully removed through the TSO. Adding a window ($n = 2$) or a transfemoral approach ($n = 4$) allowed removal of the stem in the six remaining patients, with no fractures. The cups were removed without damage to the surrounding acetabulum.

Bone loss and treatment. There was severe acetabular bone loss in 54 patients (57%), of whom 33 (35%) had cavitory defects and 21 (22%) had segmental rim defects with or without cavitory defects. The remaining 40 patients (43%) had minimal periprosthetic bone loss which did not require reconstruction procedures. Metal reinforcement (usually with a Kerboul cross-shaped plate) was used in 22 patients (23%) and deep frozen bone allograft in 17 (18%) (morsellised graft in five and either structural- or structural and morsellised-graft in 12).

There was severe femoral osteolysis in 23 patients (24%), including 15 (16%) with stage-3 (marked thinning of the lateral cortex) and eight (8%) with stage-4 damage (thinning of the medial and lateral cortices along the entire length of the prosthesis). There was moderate lateral osteolysis (stage 2) in 15 patients (16%) and minimal osteolysis mainly in the calcar (stage 1), or no osteolysis in 56 (60%).

In three patients, cortical strut allografts were wired to the femur to strengthen the lateral cortex. In 70 patients (75%), femoral revision was associated with only minor compromise of the femoral diaphysis; the distal end of the new cement plug extended no further than 6 cm below the tip of the previous stem or cement (i.e., the length of the new stem was less than 200 mm). In the remaining 24 patients (25%), extensive medial osteolysis required the use of a long femoral stem extending to a mean of 10 cm below the distal end of the previous stem (i.e., the length of the new stem was more than 200 mm), causing major femoral compromise.

Overall outcome of the revisions. Two patients were lost to follow-up after three months, with a fused osteotomy at this time. Of the 94 patients, 92 were re-evaluated after one year or longer, and 36 of these were re-evaluated after five years.

At the more recent follow-up, six patients (6.4%) had required further surgery, two for trochanteric nonunion, two for loosening of an inappropriately sized femoral stem, one for nonunion of a bone flap, and one for traumatic fracture of the femur. In the remaining 88 patients, the mean Merle d'Aubigné score was 16/18 (pain = 5; motion = 6; and walking = 5) and radiography revealed no loosening, osteolysis, or impending failure.

Discussion

Technical aspects. TSO was described for arthroplasty as early as 1954,³ for reconstruction after tumour resection in 1976,⁴ and for primary hip replacement in 1975⁵ and 1991.⁶ More recently, it was suggested for revision THA after aseptic loosening⁷ and this has gained widespread acceptance in the USA.⁸

In order to ensure healing, the blood supply and stability of the trochanter must be preserved. Although part of the blood supply comes from the attachments of gluteus medius and minimus and vastus lateralis, the main source is the anterior trochanteric artery, as demonstrated by Churchill, Brookes and Spencer⁹ and by Najima et al.¹⁰ Consequently, the osteotomy should be made in the posterior-to-anterior direction so that it is deeper than the attachments of gluteus minimus. Vertical stability is provided by three 14/10 mm wires and by the continuity between gluteus medius and vastus lateralis. This continuity reduces proximal migration of the trochanter even when the wires break. In our series, abductor strength was $\geq 4/5$ in the 12 patients whose trochanter healed with proximal migration or heterogeneous callus, and in two of the four with nonunion.

Stability in the sagittal plane is just as important because contraction of gluteus medius and minimus during flexion and extension of the hip tends to rotate the trochanter anteriorly. The presence of two anchoring points which prevent pendular movements of the trochanter is essential. The first is a wire in the transverse plane which is usually wrapped around the proximal third of the greater trochanter. The lower anchor is usually created either by making a notch in the lower edge of the greater trochanter or by placing a second transverse cerclage wire distal to the first.

Comparison between TSO and the other extensile exposures

Standard trochanteric osteotomy. This technique provides excellent exposure of the acetabulum and femoral diaphysis but has a rate of nonunion in revision cases of between 15% and 20%. Although rates of nonunion of less than 5% have been described,¹¹ most authors have reported much higher rates, with no noticeable improvement over the years as technical variations were introduced (Molé et al,¹² 16%; Langlais et al,¹³ 14%; Bal, Maurer and Harris,¹⁴ 13%; Jensen and Harris,¹⁵ 13%; Courpied and Migaud,¹ 19%; Nicholson, Mulcahy and Fenelon,¹⁶ 23%; and Hawkins, Midwinter and Macdonald,¹⁷ 18.5%). The rates of nonunion are higher in patients with marked lateral osteolysis. Although Hawkins et al¹⁷ reported little effect on instability of gait, most authors suggested an association with instability and limping. Langlais and Thomazeau¹⁸ reported increased loosening of components in physically active patients with nonunion. Other investigators¹⁹ have implicated third-body wear of polyethylene by the intra-articular penetration of cement or metal debris in association with trochanteric fixation by cables as an aggravating factor. Consequently, standard trochanteric osteotomy should be

reserved for the small number of patients in whom it is unavoidable, such as those who need massive acetabular allografting which requires the extensive exposure provided by the Ollier approach, and which includes a trochanteric osteotomy.²⁰

Extended TSO. This technique has been described by several authors, including Younger et al.²¹ The osteotomy starts 8 to 20 cm below the tip of the greater trochanter and ranges in length from 12.5 cm²² to 14 cm.²³ This long osteotomy allows removal of prostheses which are secured to the proximal part of the isthmus, particularly those inserted without cement. Horizontal cerclage wires are used to close the osteotomy. Because it extends further along the lateral aspect of the femur, a longer stem must be used since the tip of the stem must be at least 6 cm distal to the lower end of the lateral cut. This implies the use of a stem at least 200 mm in length. In the series of Miner et al.²³ the mean length of stem beyond the osteotomy line was 14 cm (12.5 + 14 = 26.5 cm below the tip of the trochanter and 22 cm below the calcar cut), which resulted in considerable additional compromise of the femoral bone.

Although healing occurred in 98% of patients after extended TSO, the process was slow,²² with the use of an abduction brace in most of the cases,²³ so that full weight-bearing had to be delayed until three months after the procedure and 14% of osteotomies were still unhealed after six months. In another series, which included 131 revisions,²⁴ the overall rate of further surgery due to nonunion, recurrent dislocation, or early loosening was 10.2%.

Transfemoral approach. This technique, which is currently popular, was described among others by Wagner²⁵ in 1992. In France, this method has been in use for many years, having been reported as early as 1986 by Vielpeau for septic loosening.²⁶ It can be performed to enhance new bone formation.²⁷ Anchoring of the prosthesis is facilitated by shrinkage of the fragments around a hydroxyapatite-coated stem.

Although the simplicity of the transfemoral approach is attractive, intraoperative or postoperative fractures of the femur have been reported in 15% of cases.¹ Another disadvantage is that the tip of the stem must be located 80 to 100 mm distal to the lower end of the osteotomy. This results in compromise of the femur which can limit future options in younger patients.

Trochanteric slide osteotomy (TSO). This technique has many advantages over those described above, including a high rate of union (96% in our study), a very low rate of femoral complications (no perforations, 2% fractures), limited further femoral bone compromise in 75% of patients, and compatibility with various other treatments such as allografting and the use of either standard or long prostheses. Versatility is another advantage of the use of TSO. A distal femoral window can be cut to remove a well-fixed cement plug, and preservation of the integrity of the proximal femur allows the use of a standard stem, extending only 1 cm to 2 cm below the lower edge of the window.

We conclude that in patients with aseptic loosening, TSO is of interest for revision procedures of intermediate difficulty because of the risks involved in the removal of the previous prostheses or the need for wide exposure in order to reconstruct bone loss with allografts, substitutes, or other devices.

The rate of trochanteric union is high and the strength of the abductor muscles is preserved. Of our 94 patients, only four had nonunion, and only two of these four required further surgery. In the two other patients with nonunion and in the 12 with union after proximal migration (8 mm) or with heterogeneous callus, the strength of the abductor muscles was at least 4/5, as a result of the continuity of vastus lateralis and gluteus medius.

The absence of a long lateral osteotomy, such as with a femoral flap or extended TSO procedure, made it possible to use femoral stems of 200 mm in length or less, thus preserving the intact femur in 75% of cases. This is of importance in younger patients in whom the need for further revision may occur within two decades, and the prognosis is better if the distal half of the femur is intact.

In 25% of patients, after TSO and preparation of the proximal femur, the extent of the osteolysis was found to require a long prosthesis. The advantage of TSO in these patients was to allow full weight-bearing after only six to eight weeks instead of three months with the femoral flap or extended TSO procedures.

TSO provided adequate exposure for removal of the prosthesis without complications and for reconstructing bony defects.

Removal of the stem was possible using TSO in 82 patients, including 30 who had no loosening of the distal cement which secured the stem and 12 who had porous ingrowth prostheses. In only 12 patients, including the four with fully porous-coated stems, removal of the stem required a window or flap. An additional advantage of TSO is thus the possibility of conversion to a wider approach without further morbidity. There were very few complications, which included two perforations without adverse consequences and one nonunion of a femoral flap. The approach was wide enough to allow complex reconstructions of the acetabulum (18% allografts, 23% reinforcement plates) and of the femur. Our present choice for the reconstruction prosthesis (Charnley or hydroxyapatite-coated) does not depend on the approach, but on the site and extent of the osteolysis. When distal fixation is necessary, however, especially in a narrow femur, we now prefer a hydroxyapatite-coated prosthesis with a long interlocked stem, which offers better resistance to rotation than a thin cemented stem.

Thus, we choose our method according to the situation. Many revisions are *simple*, in that they do not require major reconstruction. In these cases, revision should be performed without a TSO. We use the extended posterior approach, which can be converted to a TSO. Conversely, in cases of *gross loosening* in older patients with poor bone stock, or

when a femoral tubular allograft is required, we prefer distal anchoring of a long prosthesis which is facilitated by a transfemoral approach. Loosening of *intermediate* difficulty is associated with major bone loss, either of the acetabulum with a segmental or global defect, requiring allograft²⁷ and/or reinforcement, or of the femur with stage-3 or stage-4 osteolysis, sometimes requiring allograft or distally fixed prostheses. In these cases, TSO gives ample exposure which facilitates removal of the prosthesis, bone preparation, and reconstruction of the acetabulum and femur, while providing a very high rate of healing (96%) and, in 75% of cases, limited femoral compromise. This preservation of the femur is crucial in patients with a long life expectancy.

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