Total hip replacement for developmental dysplasia of the hip

How I do it

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Total hip replacement (THR) for developmental dysplasia (DDH) or congenital dislocation of the hip (CDH) is technically demanding. Good technical solutions have been developed, even for the most difficult stages of the deformity and good or excellent function can be achieved in most cases. In young individuals, late loosening of the components is still an unsolved issue and therefore, the indications for THR should be carefully considered. On the other hand, smooth and painless gait is important when young and active.

Classification of the deformity

When planning THR, the height of the dislocation is much more important than the acetabular angle or center-edge angle. The Eftekhar 4-stage classification is useful and it also defines the height of the dislocation (Eftekhar 1978). In stage A, the acetabulum is slightly elongated and dysplastic, with some deformation of the head. In stages B and C with an intermediate and high false acetabulum, the true acetabulum is rudimentary or poorly developed. In stage D, the femoral head has never been in contact with the ilium.

The classification by Crowe et al. (1979) is more complicated and includes no additional information. Kerboul et al. (1987) classify the DDH hips as anterior, intermediate or posterior, on the basis of the pathological anatomy. The anterior ones are low subluxations, equal to A and B stages of Eftekhar, intermediate ones are higher subluxations equal to stage C, and the posterior dislocations are high and unstable, like Eftekhar stage D.

Pathoanatomic features

Pelvis and acetabulum

Many specific anatomic abnormalities of the pelvis are related to the stage of the developmental dysplasia. In hips with low subluxation (stages A and B), the shallow acetabulum, either original or false, has a wide opening and is oval in shape, according to the degree of anteversion of the proximal femur and deformity of the femoral head. The medial wall of the anterior acetabulum may be very thin, but fortunately it is thicker posteriorly.

In cases of high dislocation (stages C and D), the affected side of the pelvis is smaller, bony structures are thinner and the acetabular bone is soft and porotic. The lateral wall of the pelvis is often in excess anteversion. The original acetabulum is rudimentary, tepee-shaped, full of fat and fibrous tissue, and the anterior wall is atrophic or missing. However, the most important part of the available bone stock is still found at the level of the original acetabulum (Charnley and Feagin 1973, Dunn and Hess 1976, Harris et al. 1977, Eftekhar 1978, Mendes 1981). Fortunately, one finds, as a rule, a bony prominence near the junction of the pubic bone and ilium at the level of the anterior inferior iliac spine. The superior ischium is often prominent laterally. The sagittal diameter of the ilium is distinctly reduced above the level of the original acetabulum.

Proximal femur

A coxa valga deformity is common in subluxated hips. Indeed, the proximal femur is markedly anteverted and the greater trochanter retroverted. If growth disturbances of the femoral head and neck are secondary and caused by earlier operations, a severely anteverted coxa plana may be associated with a high-standing retroverted greater trochanter.

In hips having a high unstable dislocation without any false acetabulum (stage D), the femoral head is small, porous and with increasing age the surface of the head roughens along with involutional atrophy of the cartilage; the neck is short and moderately anteverted. The metaphysis and proximal diaphysis are straight, oval in cross-section, the greatest diameter being in the sagittal plane (Dunn and Hess 1976, Eftekhar 1978, Crowe et al. 1979, Mendes 1981).

The anatomy of the proximal femur is most markedly changed in hips where a Schanz osteotomy has been performed to improve the Trendelenburg limp.

Other hip-related problems

Problems secondary to DDH are due to the deficient abductor mechanism and leg length inequality. In subluxated hips, the lateral hip center, shortened femoral neck, and high-standing greater trochanter are the reasons for reduced abductor strength. In hips with an unstable high dislocation (stage D), the abductor mechanism is nonexistent, because there is no stable contact between the femur and pelvis. Reduced or absent abductor strength results in the characteristic "duck gait" with positive Trendelenburg sign. Leg length discrepancy leads to secondary scoliosis. A posterior shift of the femoral head increases the anterior tilt of the pelvis, which is compensated by hyperlordosis of the lumbal spine. These deformities are likely to cause chronic low-back pain (Mendes 1981, Kerboul et al. 1987, Morscher 1995).

Valgus deformity and arthrosis of the lateral compartment of the ipsilateral knee are often seen as a result of the lateral hip center and "duck gait" (Mendes 1981).

Indications for THR

Gradually increasing pain due to secondary arthrosis associated with subluxation of the hip is the main indication for THR. The patients are often middle-aged or younger. Sudden onset of severe pain may occur in hips with an unstable high dislocation. Rupture of the capsule and brownish discoloration of the capsular tissue due to hematomas are often found at surgery. These patients are often elderly with roughened femoral head.

Increasing low-back pain, problems in the ipsilateral knee, contractures of the hip and unsightly waddling gait may gradually become so disturbing that THR is desired. The indications should be still stricter in younger patients because of the life expectancy of each THR is limited and several revisions may be necessary during the years to come (Maloney and Smith 1995).

Planning the operation

While the main purpose of the hip replacement is to eliminate pain, it is also important for a young or middle-aged person to achieve a smooth gait without a limp. This goal can be attained if the center of rotation is relocated at an anatomical level or even lower and if an abductor mechanism, strong enough to balance the pelvis, can be reconstructed. The leg-length inequality should be abolished or corrected to an appropriate extent.

Clinical leg-length inequality is measured with the patient standing and a lift placed under the shorter leg to balance the pelvis. Full correction of the leg-length discrepancy is indicated only in younger patients with a mobile lumbar spine, especially if they compensate the discrepancy with elevated footwear. For older patients with fixed scoliosis, the appropriate lengthening is decided by selecting the most comfortable lift height. For the preoperative planning, an anteroposterior radiograph should be taken in an erect position with an appropriate lift under the shorter leg and a plumb line as the vertical reference line (Hoikka et al. 1993). As a rule, this view and a lateral radiograph are sufficient for planning the THR. CT with 3-dimensional reconstruction is necessary in exceptionally deformed cases.

The acetabular component should be placed at the anatomic site. One should be prepared to insert it even lower, if the sagittal diameter at the anatomic level is too small for the prosthesis. This component should also be inserted as medially as possible to reduce the abductor force needed to balance the pelvis. At the same time, wide perforation of the medial cortex should be avoided.

The level of resection of the femur is estimated with templates, according to the need for lengthening, and the type and size of the femoral component is chosen according to the configuration of the femur at the level of resection (Figure 1). An ordinary stem

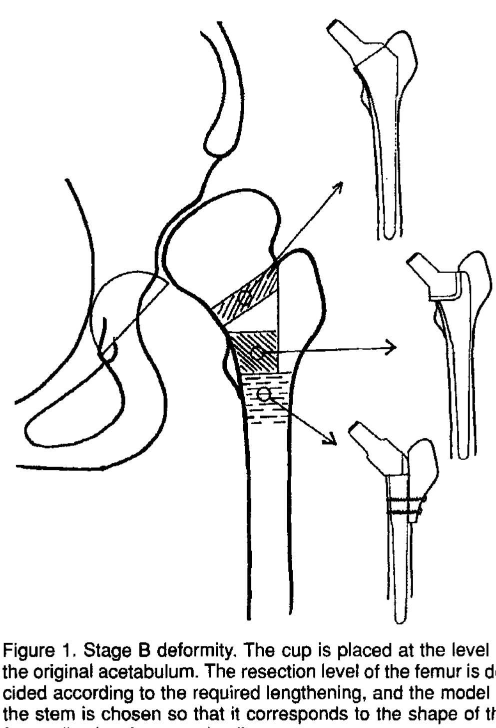

Figure 1. Stage B deformity. The cup is placed at the level of the original acetabulum. The resection level of the femur is decided according to the required lengthening, and the model of the stem is chosen so that it corresponds to the shape of the femor distal to the resection line.

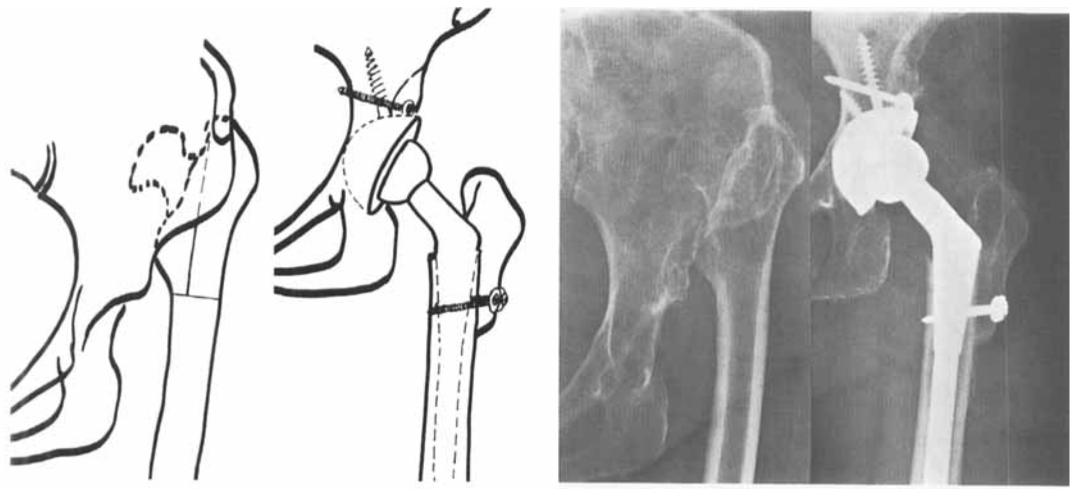

Figure 2. Old, unreduced dislocation (stage D). The cup is placed at the original level or even lower. The proximal femur is shortened according to the required functional lengthening and distal advancement of the greater trochanter is performed.

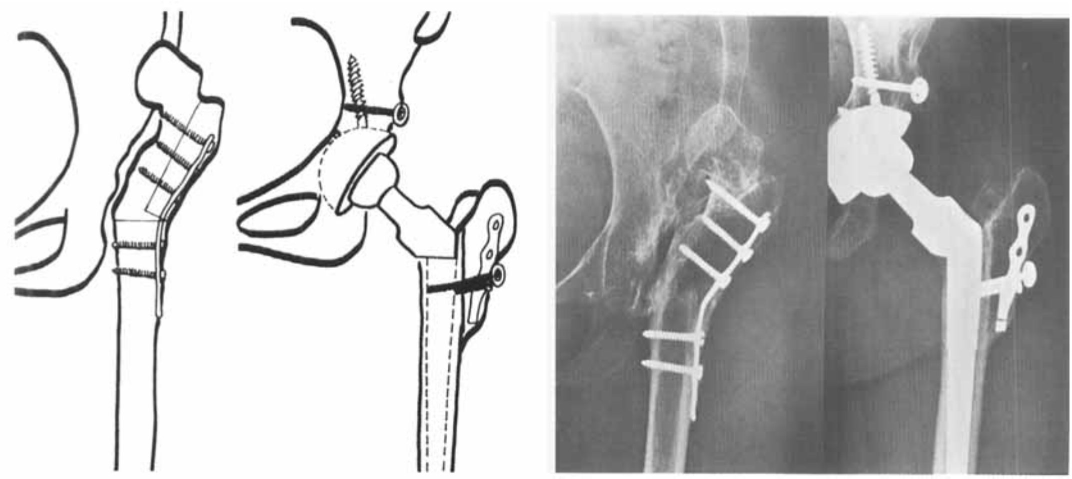

Figure 3. A hip after high-seated Schanz osteotomy is treated with the same principles as a neglected high dislocation (Figure 2). The resection level is near the angle of Schanz osteotomy or more distal according to the required functional lengthening.

with an anatomic calcar curve is appropriate in many subluxated hips with stage A and in some cases with stage B deformity, if sufficient medial calcar curve is left. The femur with a deficient medial calcar curve may be properly treated with a head-neck type stem. In cases with a very deficient or missing medial calcar curve, a totally straight DDH stem is needed. The resection level of the femur in hips with high subluxation (stage C) or dislocation (stage D) is so low, as a rule, that no calcar curve is left and the stem must be straight (Figure 2).

A hip after a subtrochanteric Schanz osteotomy needs special consideration. If the osteotomy has been performed near the lesser trochanter, the stem should be placed at the level of the osteotomy, and the greater trochanter can be transferred without problems (Figure 3). However, this method does not permit sufficient lengthening of the femur after a low-seated unilateral Schanz osteotomy. These femora are best treated by segmental resection of the angulate metaphysis. The required shortening and the angular and rotational corrections are estimated when planning the procedure, and a step method is used to stabilize the osteotomy against rotation. The femoral stem acts as an intramedullary nail (Figure 4). The stem is chosen according to the shape of the proximal femur, and sometimes longer stems may be necessary.

The oval femoral canal may be too narrow in the frontal plane, even for the smallest available stem. For planning, the femoral canal can be measured accurately with CT. The problem of a too narrow canal can be solved by splitting the proximal femur 8–10

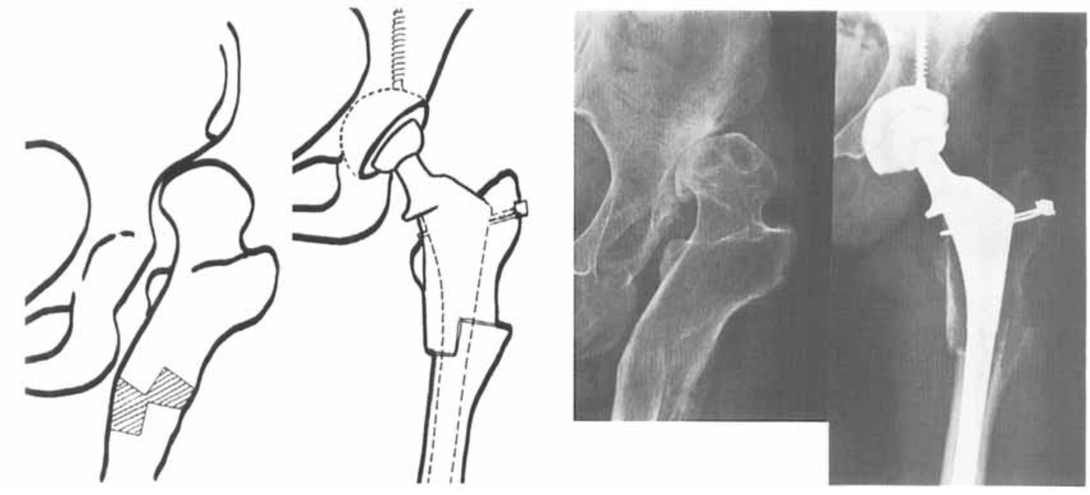

Figure 4. A hip after unilateral low-seated Schanz osteotomy is treated with segmental shortening osteoplasty combined with angular and rotational correction. A step method is used to stabilize the osteotomy against rotation.

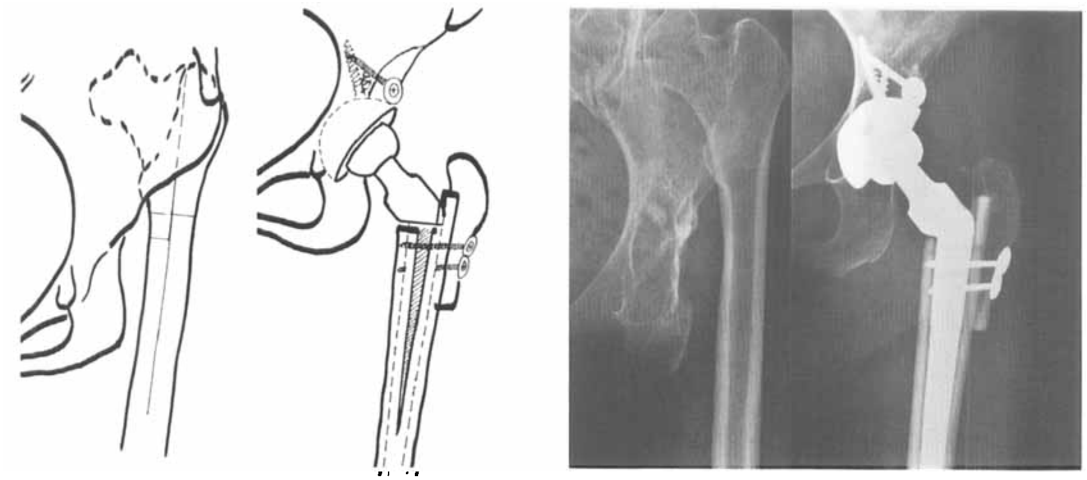

Figure 5. If the femoral shaft is too narrow for the smallest stem, it is split both anteriorly and posteriorly. First then the medullary canal is prepared for the stem. The splits are filled with cancellous bone and fixed by the lag screws used to secure the greater trochanter.

cm both anteriorly and posteriorly (Figure 5).

In bilateral cases, the more painful hip should be operated on first. Bilateral stage A and B deformities can be operated on in one stage, but the bone around the cup after high subluxation or dislocation is too porotic to allow immediate full weight bearing.

Operative techniques

I use a posterolateral Moore approach in most cases. Only in hips previously treated with a low-seated Schanz osteotomy do I prefer an anterolateral exposure according to Hardinge, with the patient in a lateral position. The sciatic nerve should always be identified. Alteration of the leg length is assessed by the change in the distance between 2 reference points: a Kirchner wire is driven into the iliac crest, and the other point is marked by an awl in the greater trochanter or, in the hips with femoral osteoplasties, in the diaphysis or in the lateral femoral condyle. In cases with unstable high dislocation, the leg must be pushed upwards when the initial distance of the reference points is measured. All the osteoplasties are performed with minimal periosteal stripping to avoid devitalization of the bone. Subcutaneous adductor tenotomy is performed, if the abduction is restricted.

THR in stage A deformity presents no greater problem than a hip with severe arthrosis. The medial wall of the acetabulum is thick in many subluxated hips. It should be reamed as far as the inner cortex, just avoiding perforation, in order to insert the cup as medially as possible to achieve maximal abductor force. A high hip center should be avoided. If a superior rim defect remains, it is augmented by bone grafts obtained from the removed femoral head. Increased anteversion of the proximal femur is reduced to 5–15 degrees. In most cases, it is easiest to rasp the correct anteversion when preparing the femur and to use the head-neck stem, with reduced calcar curve. Derotational osteotomy is more complicated and is reserved for cases with extreme anteversion.

In hips with stage B deformity, the new acetabulum is reamed as far as the inner cortex in the inferior part of the elongated original acetabular cavity, and the defective superior rim of the new acetabulum is reinforced by a bone graft from the excised femoral head.

The deformity of the proximal femur varies greatly according to the growth disturbances secondary to previous treatment. Proximal resection of the femur is performed according to the preoperative planning (Figure 1) and the stem is chosen according to the shape of the femur distal to the resection line. A stem with a normal calcar curve is used if the medial calcar is preserved, a head-neck stem is used in cases with reduced calcar curve and a totally straight stem in femora without any calcar. Tight soft tissues may demand a more distal resection level than planned preoperatively. If the greater trochanter remains too high, distal transfer of the trochanter with intact attachment of the gluteus medius muscle is performed, using screw fixation, and the vastus lateralis muscle is tightened.

In hips with high subluxation (stage C) or unstable dislocation (stage D), shortening of the proximal femur with distal advancement of the greater trochanter is performed (Figure 2). The proximal part of the vastus lateralis muscle is divided and the posterior half is released from the base of the greater trochanter. The femur is cut 7–9 cm distal to the apex of the greater trochanter on the basis of preoperative planning. The medial half of the proximal femur is removed. The greater trochanter with the intact attachments of the gluteus medius and the anterior half of the vastus lateralis muscles is pulled anteriorly.

In this phase, an excellent access to the lateral wall of the pelvis and acetabulum is achieved and the acetabular preparation is performed. The elongated hypertrophic joint capsule is resected and the small tepee-shaped, fibrous fatty tissue-filled acetabulum is identified. The proximal parts of the pubic and ischial bones are exposed for orientation and evaluation of the bone stock. The new acetabulum is formed around the original one. If the sagittal diameter is too small at this level, the cup is placed more inferiorly. As a rule, there is an anterolateral bony prominence beside the inferior iliac spine, which offers reliable anterosuperior support, and the junction of the ischial bone to the ilium gives excellent posterosuperior support for the acetabular component. In many cases the superior rim between these is defective so it is reinforced with a bone graft from the excised femoral head.

In some cases the pelvic bone is so thin that fixation of the cup in the remodeled shallow acetabulum is not reliable. In such cases, the central part of the medial wall can be detached from the pelvic bone and pushed inwards, while preserving its periosteal attachments, and the lining cap is augmented by cancellous bone (Hess and Umber 1978). The superior rim is reinforced by a bone graft if needed.

When the acetabular component has been mounted, the femur is prepared for the straight stem and the prosthesis reduced with an appropriate modular head. Today I perform the reduction under control of electromyographic monitoring (Daube and Harper 1989) to avoid injuries of the sciatic nerve. If reduction of the prosthesis is not feasible or is too tight, even after tenotomy of the tight adductor tendons, the diaphysis is resected more than was planned preoperatively.

After reduction of the prosthesis, the greater trochanter is shaped concave to fit on the proximal diaphysis and it is then advanced distally far enough to tighten the abductor muscles, and is fixed with screws, which are driven both anterior and posterior to the stem. Fixation of the trochanter is performed with the hip in wide abduction. As a rule, the tight tendinous central part of the gluteus medius must be released to get the trochanter down far enough. The posterior half of the vastus lateralis muscle is tightened and fixed to the greater trochanter and the loosened anterior part of the muscle is duplicated. By this method, functional lengthening of the leg becomes possible up to 5 cm. This type of osteoplasty is applied to the femora after a high-seated Schanz osteotomy also. The resection level is near the angle of the earlier Shanz osteotomy or distal to that (Figure 3).

If the femoral shaft is too narrow for the stem, it is split both anteriorly and posteriorly for 8–10 cm, before the medullary canal is prepared. The splits are filled with cancellous bone, the posterior one from within before the stem is inserted. The splits are fixed with lag screws to secure the greater trochanter (Figure 5).

A femur after a low-seated unilateral Schanz osteotomy is treated with metaphyseal segmental shortening, combined with angular and rotational correction (Figure 4). An anterolateral approach is appropriate for this procedure. The amount of shortening is estimated in advance, according to the preoperative planning. Both the proximal and distal parts of the femur must be reamed carefully to achieve accurate fitting of the prosthetic stem and the osteotomy line. A step method is used to stabilize the osteotomy against rotation. The osteotomy should be at the level of the porous coating of the stem to achieve more stability. Trimming of the osteotomy line is aided by inserting the broach through the reduced osteotomy into the intramedullary canal. Usually, a stem with a normal or a reduced calcar curve is appropriate, while a straight stem is seldom required. However, relatively long stems may be necessary. By this method, the leg can be lengthened functionally up to 3 cm.

The components I use for these hips are cementless (Biomet, Warsaw, Indiana, USA or Bridgend, Wales, United Kingdom). I have used a porous-coated press-fit Universal® cup since 1989. The stem is Bi-Metric® with a normal calcar curve and with a proximal porous coating. The stem with a reduced calcar curve is the Biomet head-neck model. The totally straight stem is made of titanium alloy, it has a collar and a wedge shape of three degrees. The proximal third is porous-coated, and is oval on section. The neck angle is 135 degrees, and the offset of the stem varies from 31 to 39 mm, according to the choice of modular head. The length of the intramedullary part of the stem is 15 cm. We have used a collarless straight stem in a clinical trial series since 1992. With this type of stem, the femur is prepared with reamers, but not broaches. The screws for fixation of the greater trochanter and bone grafts, are self-tapping and made of chrome-cobolt (Duo-Drive Head Cortical Screws®, 3.6 mm Self-Tapping, Howmedica, Limerick, Ireland), and are usually inserted with a washer.

Zirconia-ceramic prosthetic heads (delivered by Biomet) are used for younger patients to reduce polyethylene wear.

Postoperative management

On the day after operation, the patient is allowed to stand and take a few steps. On the next day, she begins to walk, bearing partial weight with crutches. If the abductors are very tight, the patient is allowed to stay in bed for a couple of days with isometric exercises. Progressive flexion, extension and abduction exercises are started immediately, but abduction against resistance is started only after 6–8 weeks. After this, progressive increase in weight bearing is allowed, according to radiographic consolidation of the osteoplasty. The ipsilateral crutch is discarded 2 months after the operation, but the contralateral one is used until the abductor muscles are strong enough to balance the pelvis and abolish limp, usually 4–6 months after the operation. To achieve this intensive abduction exercise is essential.

Outcome of a previous series

During 1982–1986, we treated 100 severely dysplastic or dislocated hips with uncemented Lord arthroplasties and reported the outcome (Paavilainen et al. 1990). The main principles of the osteoplasties we use today were developed on basis of this work. During later follow-up, the femoral components have fared well, but the loosening rate of the threaded acetabular component has been unacceptably high (Engh et al. 1990, Snorrason and Kärrholm 1990, Tallroth et al. 1993).

We have also reported the experiences of the straight cementless stem after 3–5 years' follow-up (Paavilainen et al.1993). The straight stem was used in 67 hips (60 patients), 58 of these were DDH cases of Eftekhar stages B, C, and D; the rest were severely dysplastic hips after tuberculous coxitis, congenital coxa vara, etc. Of the patients 55 were women and the mean age at operation was 52 (24–76) years. The main steps of the operations were similar to the procedures described above. The segmental shortening osteotomy, combined with angular correction and derotation of the metaphysis, which was generally used for high dislocations in the first series, is tedious and time-consuming. It is also likely to be experienced as complicated, when adopted more widely. Therefore we suggest this procedure only for cases after unilateral low-seated Schanz osteotomy.

Pain was consistently relieved. The mean pain score (Mayo Hip Score) was 17/40 (0–20) before the operation and 39/40 (35–40) after it. All patients had a limp before the arthroplasty, 62 having a positive Trendelenburg sign, which was severe in most cases. Postoperatively, the Trendelenburg sign was slight in 5 hips and negative in 62. Before the operation, 37 of 60 patients used walking aids and 4 needed crutches. After the operation, 3 patients used a stick regularly and 4 occasionally. The mean clinical leg-length inequality before operation was 34 (0–80) mm and after operation 12 (0–40) mm.

Complications

In 5 of the 67 hips, the metaphysis was accidentally split, 2 of the splits being medial. The medial splits were fixed with a Parham band. The others were located anteriorly or posteriorly, and were fixed with lag screws to secure the greater trochanter. Each time, the outcome was uneventful. There were no nerve injuries or infections. All the transpositioned greater trochanters united. In 2 cases, the proximal part of the femur fractured 2 and 4 weeks after the segmental shortening angle correction procedure. These fractures were successfuly treated with hook-plate fixation and bone grafting. There was one late dislocation treated with closed reduction, without recurrence.

During 1988–1989, the smooth-threaded cup (TTAP/ST®, Biomet) was still in use, but during this time it became apparent that these acetabular components tended to loosen and the porous-coated press-fit cup (Biomet Universal®) was adopted in 1989. In our series, the threaded cup was used in 50 hips, and during the follow-up time nearly one half of them were revised because of loosening. All the press-fit acetabular components are still well fixed.

Loosening of the femoral stem occurred in 4 hips; 3 of them resulted from the same technical error. The greater trochanter had been detached so far distally, that the lateral support of the stem was insufficient to give reliable rotational stability. The fourth loosened stem was evidently too small and the rotational stability deficient.

Discussion

The main goal of replacement surgery of DDH hips is to reconstruct a hip joint which functions as nearly normally as possible. To achieve this, the main prerequisite is to restore the abductor mechanism. The rotation center should be seated near the anatomic position in both the coronal and sagittal planes (Charnley and Feagin 1973, Dunn and Hess 1976, Fredin and Unander-Scharin 1980, Mendes 1981, Hartofilakidis et al. 1988, Linde et al. 1988, Garvin et al. 1991, Morscher 1995). The offset of the stems we use gives sufficient lever arm for the abductor muscles. The chief abductor muscle, the gluteus medius, must be tightened and its lever arm is increased with distal and lateral placements of the greater trochanter (Vasavada et al. 1994). Tightening of the gluteus medius muscle is balanced by tightening the vastus lateralis muscle.

Adequate lengthening of the leg is also important. With present techniques, functional lengthening of the leg is possible for 3–5 cm. The method of shortening the proximal femur, combined with distal advancement of the greater trochanter, allows functional lengthening of the leg up to 5 cm, but it is limited to 3 cm with the method of segmental shortening, combined with the angle and rotation correction used for hips after unilateral low-seated Schanz osteotomy. Further lengthening is limited by tight soft tissues and especially by the sciatic nerve. In many cases, it is difficult to estimate the optimal amount of lengthening. The younger the patient, the more we try to achieve equal length, especially if they have compensated the inequality with elevated footwear. Patients with a fixed degenerative low back must be carefully tested preoperatively with various elevations (Hoikka et al. 1993).

There were no neurological complications in the series we have reported, but we have since seen some injuries to the peroneal division of the sciatic nerve. These cases have been explored immediately. They have slowly recovered after removal of the postoperative hematoma. A few cases without noteworthy recovery were hips with severe dysplasia or dislocation after purulent or tuberculous coxitis in childhood. We found no hematoma at the exploration, but the nerve was abnormally adherent. Today we use peroperative electromyographic monitoring (Daube and Harper 1989) if marked lengthening is expected and, before closure, function of the sciatic nerve is assessed by stimulating the nerve. Postoperatively, full extension of the hip joint and flexion of the knee reduce tension of the sciatic nerve (Morscher 1995). We have seen a single case with adductor muscle paralysis related to injury of the obturator nerve, which was evidently caused by a retractor placed around the tear drop.

Screw fixation of the greater trochanter has proved to be reliable. The medial surface of the trochanter is shaped concave to achieve close contact for fixation and union. The lag screws must be carefully tightened. The detached trochanter should be thick enough for reliable fixation, which is beneficial for the abductor mechanism also. Screws seem to be more reliable than wires for fixing the greater trochanter. Anwar et al. (1993) reported symptomatic nonunion of the greater trochanter after wire fixation in 10 of 34 cases, 9 of them developed in hips where lengthening exceeded 2 cm.

Fusion of the bone grafts used to reinforce the defective proximal rim of the remodeled acetabulum has been no problem. Mulroy and Harris (1990) reported long-term (average 12 years) results of acetabular autogenous grafts. The failure rate was 64% in hips where 40–70% of the cup was supported by the graft. If the cup was supported less than 40% by the graft, the loosening rate was 21%. The technique we use allows more medial placement of the cup, so the proximal defect remains as a rule less than one third of the weight bearing surface of the cup. Our results compare well with those of Hintermann and Morscher (1995).

Valgus deformity of the ipsilateral knee is common, particularly after Schanz osteotomy. A medially located diaphysis of the femur and lateral displacement of the proximal femur shift the weight bearing line laterally in the knee and cause increasing valgus deformity and arthrosis of the lateral compartment. Although the arthroplasty corrects the rotation center of the hip, and shifts the weight bearing line medially, the lateralizing effect of the femoral shaft associated with hip replacement can even aggravate the valgus deformity of the knee (Mendes 1981, Morscher 1995). This is corrected with a supracondylar dome osteotomy of the femur or arthroplasty of the knee, either unicompartmental or total, according to the stage of arthrosis.

The collarless stem, still in the clinical trial series, offers some remarkable advances. Preparation of the femur is performed with reamers, no broaches are needed. By this procedure, the risk of proximal splits is evidently reduced. The vertical stability should be achieved by the wedge shape of the stem, not by the collar; otherwise the rotational stability may remain deficient and result in loosening of the stem.

The techniques developed for replacement of these problematic DDH hips are suitable for replacement surgery of any type of secondary, arthrosis including severe deformities after Perthes' disease, congenital coxa vara, diastrophic dysplasia, slipped femoral epiphysis, old tuberculosis, ankylosis, etc. The function depends first of all on the condition of the abductor muscles. It is astonishing to see how well the strength of the abductor mechanism is restored when previous surgery has not denervated or destroyed the gluteus medius muscle. Although this type of surgery is demanding, it is highly rewarding to observe these crippled people achieving normal or much improved gait and walking. However, the patient must be well motivated both for the surgery and the intensive postoperative exercise program.

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