Acetabular dysplasia is an established cause of hip arthritis.\textsuperscript{1,3} In dysplasia, abnormal loading occurs at the edge of a steep and shallow acetabulum which may lead to osteoarthritis. Stulberg and Harris,\textsuperscript{4} in their classic study of 130 patients with total hip replacement, found that 63 (48\%) patients with degenerative arthritis had acetabular dysplasia. Early recognition of dysplasia of the hip is important to allow the opportunity for timely intervention. This article will consider the various pelvic and acetabular osteotomies used to treat dysplasia of the hip, together with their relative advantages and limitations.

**Treatment of acetabular dysplasia**

The goal of treatment in acetabular dysplasia is to establish normal biomechanical forces around the hip joint. Acetabular osteotomies aim to increase the contact area, reduce the contact stresses and normalise the weight-bearing forces.

In terms of treatment options patients may be split into two main groups. Those patients with concentric hips and minimal osteoarthritis require reorientation procedures. This is where the acetabulum is rotated into a better position to increase the contact area. These include Salter, Triple Innominate, Double Innominate and Periacetabular osteotomies.

In contrast, salvage or augmentation procedures are designed for patients with incongruent hips. The deficient acetabulum is supplemented by a buttress of bone to increase the area of support for the femoral head; examples include the Chiari osteotomy and Shelf procedures.

**Re-orientation osteotomies**

**Salter single innominate osteotomy.** Salter described his innominate osteotomy for acetabular dysplasia in children older than 18 months of age.\textsuperscript{5} The osteotomy is transverse and perpendicular to the iliac axis from just above the anterior inferior iliac spine to the sciatic notch. Salter stated that after the osteotomy, the symphysis pubis can be used as a flexible hinge and the acetabulum can be redirected to cover the anterolateral deficiency in a concentrically reduced hip. Salter recommended this procedure in patients up to ten years of age.

In a review of 15-year data on 140 patients, Salter and Duboss\textsuperscript{6} reported 93.6\% excellent or good results in patients from 18 months to four years of age with no failures. In the four- to ten-year-old age group, the results were excellent or good in only 56.7\%. The Salter osteotomy is, therefore, generally not recommended in older children.

**Triple innominate osteotomy.** In older children the symphysis is less flexible and Steel recommended a triple innominate osteotomy.\textsuperscript{7} This comprises osteotomies to the ischium and pubis in addition to a Salter osteotomy. The procedure allows increased mobility of the acetabulum for correction. In Steel's original series, the results were satisfactory in 19 out of 23 patients with a follow-up from 2–10 years. Joseph et al\textsuperscript{8} also reported favorable biomechanical and functional outcomes in 17 patients (22 hips) with follow-up from 2.2 to 13.8 years.

Steel's triple osteotomy requires two separate incisions for the three osteotomies. The resulting acetabular fragment is quite big and the attached soft tissues, especially the sacro-pelvic ligaments, limit the amount of correction that can be achieved. The large size of the acetabular fragment also makes it difficult to maintain the desired correction. Steel, therefore, used a combination of internal fixation and a spica cast in the initial post-operative period.

**Double Innominate Osteotomy.** Sutherland and Greenfield\textsuperscript{9} described their double osteotomy in 1977. They thought the addition of a pubic osteotomy to a Salter osteotomy would be enough to obtain correction. They recommended placing the pubic osteotomy medial to the obturator foramen in the interval between the pubic tubercle and the symphysis pubis. They explained that medial displacement of the acetabulum was possible by removing a bony segment from the pubis at the osteotomy site with the rotation achieved through the iliac osteotomy. There was a reported improvement in the centre-edge angle of 27° and a decrease in the acetabular index of 19.5°. However, he also reported significant complications including inadequate correction requiring revision, non-union and iatrogenic urological injuries.\textsuperscript{9}

**Dial or Spherical osteotomy.** Multiple centres have described spherical or dial osteotomies, each with different modifications.\textsuperscript{10, 13} The osteotomy described by Eppright\textsuperscript{11} is barrel shaped along the anteroposterior axis. It allows excellent lateral coverage but limited anterior coverage. The other spherical osteotomies provide good lateral and anterior coverage but allow only limited correction of version and mediolateral displacement of the acetabulum.

Spherical osteotomies require extensive operative exposure. The resulting acetabular fragment relays on the capsular blood supply and is, therefore, at significant risk of avascular necrosis.\textsuperscript{14, 15} Furthermore, there is the potential for intra-articular extension of the osteotomy. Hence, spherical osteotomies are technically challenging. However, satisfactory results are reported in several studies. Michael et al\textsuperscript{16} reported 84\%...
survival in 22 hips at 20 years, with total hip replacement as the end-point.

**Periacetabular osteotomy.** The Bernese periacetabular osteotomy was described in 1988. Three osteotomies are performed through the ischium, pubis and ilium. A vertical posterior cut then connects the posterior extremes of the iliac and the ischial osteotomies, anterior to the sciatic notch. The result is an extra-articular polygonal osteotomy.

This procedure has well-established advantages. The supra-acetabular and acetabular branches of the superior gluteal artery remain intact and preserve the acetabular blood supply. The correction is not limited by the sacropelvic ligaments or muscles. Extensive acetabular re-orientation is possible including version and mediolateral displacement. As the posterior column of the acetabulum remains intact, it protects the sciatic nerve during the procedure and allows for minimal internal fixation and early mobilisation. Furthermore, the dimensions of the true pelvis remain unchanged. This is important as most patients are females in the reproductive age group and this maintains their ability to have vaginal deliveries.

Unlike other procedures, all the osteotomies can be performed through a single incision via a modified Smith-Petersen or ilioinguinal approach. An anterior capsulotomy can be done through the same approach for inspection of the joint and correction of impingement. The procedure can also be combined with a femoral osteotomy if required.

The effectiveness of the Bernese periacetabular osteotomy is well established. Follow-up of 20 years has been reported, showing a cumulative survivorship of 60.5% (48.8% to 72.2%) with total hip replacement or hip fusion as the end point. Although significant osteoarthritis (Tönnis grade 2) is a relative contra-indication, satisfactory medium-term outcome has been reported in patients with congruent hips. Moreover, periacetabular osteotomies do not compromise the result of a subsequent total hip replacement.

The Bernese periacetabular osteotomy is a technically demanding procedure. Inadvertent extension of the ischial osteotomy can interrupt the blood supply and cause acetabular osteonecrosis. Extension of the iliac osteotomy into the hip can result in incongruence and osteoarthritis. The iliac osteotomy can also extend into the sciatic notch destabilising the pelvic ring. Nerve dysfunction is the most common complication. Up to 35% of the patients have paraesthesiae over the anterolateral aspect of the thigh, in the territory of the lateral femoral cutaneous nerve, although this rarely requires formal treatment. Femoral nerve palsy has also been reported.

One of the most important factors affecting the incidence of complications is the surgeon’s experience. The learning curve with this procedure is steep and training in the anatomy laboratory is extremely helpful. In units with sufficient volume, major complications are rare and the operation can be performed through relatively small incisions.

**Salvage osteotomies**

**Shelf arthroplasty.** This procedure was first described by König in 1891. It was later modified by both Albee and Spitz.

Local bone is used to augment the deficient lateral acetabulum and to act as a buttress. The hip capsule separates the femoral articular cartilage from this buttress. With time the capsule is said to undergo metaplastic deformation to fibrocartilage, although there is now good evidence that this does not occur. Hamanishi, Tanaka and Yamamuro and Nishimatsu et al reported good results in patients with minimal osteoarthritis. Staheli and Chew also reported favourable results in 83% of patients over a period of 18 years. More recently, survival of 86% at five years and 46% at ten years has been reported, with hip replacement as the end point.

However, shelf arthroplasty is limited by the amount of femoral head coverage that can be achieved. The procedure also fails to address the underlying biomechanical abnormality leading to poor abductor function. The surgical exposure can also cause damage to the abductors, thereby further exacerbating this problem.

**Chiari medial displacement osteotomy.** Chiari recognised the limitations of the shelf arthroplasty and its failure to address the subluxation of the femur. Using a curved osteotomy through the isthmus of the ilium, just proximal to the hip capsule, he described how the entire ilium could be used to increase coverage and prevent subluxation. Furthermore, as the hip is medialised, the joint reaction forces and stress on the abductor muscles are reduced.

Windhager reported 236 Chiari osteotomies followed for a mean of 24.8 years with 52% clinically rated excellent or good, 30% fair and 18% poor. Increasing age and osteoarthritis were related to poor outcomes.

**Summary**

Hip dysplasia is a significant cause of hip pain and disability. Early recognition is important so that intervention can be planned before the development of degenerative changes, which can prejudice the outcome of surgery. Where possible, surgical treatment aims to re-orientate the articular hyaline cartilage in order to reduce the forces through the weight-bearing zone of the acetabulum. The Bernese periacetabular osteotomy is now considered the most versatile of the acetabular osteotomies and can produce both excellent pain relief and a return to high levels of activity. Development or progression of osteoarthritis may still occur and is dependent on congruency of the hip and the extent of degenerative change present at the time of surgery.

Mr. Mujahid J Khattak FCPS Orth., FRCS Orth, Hip Surgery Fellow

Johan D Witt FRCS Orth, Consultant Orthopaedic Surgeon

University College London Hospitals

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