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Reconstruction of neglected developmental dysplasia by total hip arthroplasty with subtrochanteric shortening osteotomy

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- Patients with neglected developmental dysplasia (DDH) face with early osteoarthritis of the hip, limb length inequality and marked disability while total hip reconstruction is the only available choice.
- DDH has severe morphologic consequences, with distorted bony anatomy and soft tissue contractures around the hip. It is critical to evaluate patients thoroughly before surgery.
- Anatomic reconstruction at the level of true acetabulum with uncemented implant is the mainstay of treatment. This requires a subtrochanteric shortening osteotomy, which can be realised using different osteotomy and fixation options.
- Although a demanding technique with a high rate of related complications, once anatomic reconstruction of the hip is achieved, patients have a remarkably good functional capacity and implant survival during long follow-up periods.

Keywords: Hip; developmental hip dysplasia; total hip arthroplasty; subtrochanteric shortening

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Introduction

Patients with untreated developmental dysplasia of the hip (DDH) may eventually develop secondary osteoarthritis, beginning in early adulthood. Arthroplasty is the main treatment of choice. In some countries, DDH is the main cause of hip arthritis especially in young adult females due to genetic and cultural reasons. The underlying pathology is unique, and presents structural features that need to be addressed in the course of treatment.

Until recently, the results of hip arthroplasty in DDH presented by various authors were disappointing. Charnley advised against arthroplasty, taking into account the high complication rate.[1] D'Aubigné reported that functional outcomes can be less favourable, despite the near-normal radiographic appearance of the reconstructed hip.[2]

Morphological changes

Due to its nature, DDH prevents normal anatomic development of the hip joint in childhood, with severe morphologic consequences. Radiographic studies by X-ray and CT have demonstrated a substantially hypoplastic bony anatomy on the proximal femur and acetabulum, including the affected hemipelvis (Fig. 1). The deformity is characterised by insufficient coverage of the femoral head, shallow acetabulum, excessive anteversion and deficient anterior acetabular wall.[3]

Soft tissue structures around the hip are generally shortened and pelvifemoral muscles are relatively atrophic, including the iliopsoas, adductors, extensors and abductors. As a result, early adductor and flexion contractures develop, tilting the pelvis both in anteroposterior and lateral planes. Weakness and inefficiency of the gluteus medius and abductors are the main concern for a stable and efficient arthroplasty and avoidance of limp. Due to the upward migration of normal hip rotation centre the direction of muscle pull is severely affected, leading to muscle imbalance and inefficiency. The femoral head is typically hypoplastic and in valgus above a short neck with a smaller offset. The head is usually in excessive anteversion, but this is highly variable.[4] The metaphyseal femur is hypoplastic and its diameter in the anteroposterior plane may be smaller than the lateral, making it difficult to use large metaphyseal 'fit and fill' type femoral stems. The medullary canal is stenotic over a large isthmic segment and frequently presents rotational deformity.

Limb length inequality and smaller femoral offset are responsible for anatomical changes in the lower extremity, both in the anteroposterior and rotational planes.[5] The pathological condition of the hip joint in patients with DDH results in developmental changes in the osseous anatomy of the knee joint, which may develop valgus deformity of the lower extremity and create problems of malalignment.

Biomechanical implications of these morphologies are impaired muscle function, relative hip instability with loss of muscle efficiency causing Trendelenburg gait, while additional abnormal stress distribution on the articular cartilage eventually leads to early osteoarthritis. This particular morphological feature increases with additional subchondral sclerosis and osteophyte formation as the arthritis evolves. Acetabular osteophytes form on the medial and superior aspects, while the region of the true acetabulum remains

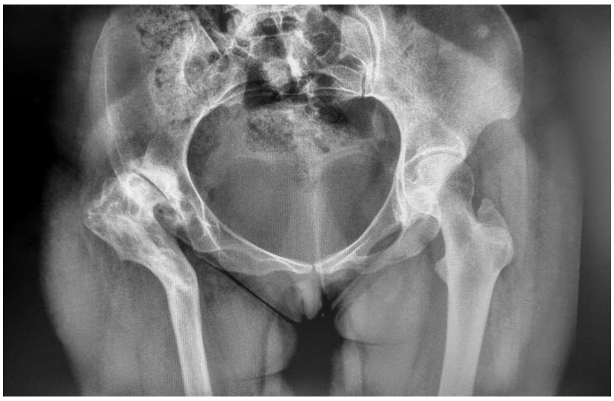


Fig. 1 A 21-year-old female patient with right hip dysplasia. She had had a previous subtrochanteric femoral valgus support osteotomy at the age of 14 years. Dysplasia is never confined to the hip joint alone but, as in this case, the whole pelvis is hypoplastic and has rotational deformity including soft tissue abnormality.

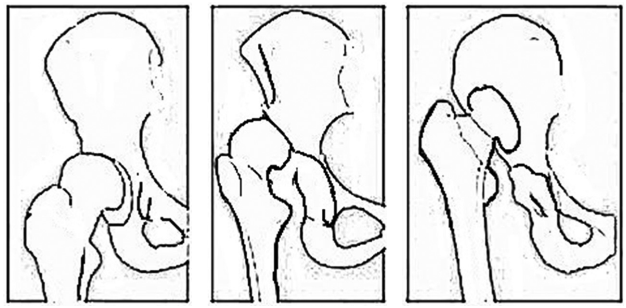


Fig. 2 Hartofilakidis Classification of Hip Dyspalsia. (Type A) femoral head is within the dysplastic acetabulum. (Type B) part of femoral head is in contact with the acetabulum. (Type C) superiorly dislocated femoral head has no contact with true acetabulum.

osteopaenic, as it is not involved in load-bearing. An understanding of the bony and soft tissue deformities is crucially important for the success of total hip arthroplasty.

Pre-operative patient evaluation

Young females with limping and postural deformity related to a marked inequality in lower limb length characterises the DDH patient with a high dislocated hip. Assessment is usually difficult; young girls can sometimes exaggerate their pain as they are anxious about their limp and deformed body posture,[4,6] whereas in severe cases limitation of the hip motion may not be obvious due to instability. The severity of the pain and the presence of any adjacent joint problems should be investigated, including lumbar spine problems, valgus knee and foot deformity, with callosities under the metatarsal heads due to tiptoe walking. Limb length inequality should be measured and recorded. Wooden blocks under the short leg help to determine the degree of correction of the pelvic obliquity.

Imaging

Anteroposterior and lateral plane leg length radiographs should be obtained for all patients. A shallow acetabulum is virtually always deficient on the anterior wall. The absence of a radiological ‘teardrop’ formation indicates the lateral position of the acetabulum. According to the Hartofilakidis classification, the existence and relationship of the false to the true acetabulum differentiates between three distinct types[7] (Fig. 2).

Subtrochanteric shortening is indicated in the most severe cases, where the true and false acetabula are different with the false acetabulum riding high over a well-preserved iliac bone. In the most severe conditions, there is no false acetabulum formation and the femoral head resides within the soft tissues, covered by the capsule. In this situation there is no bony contact and thus no arthritis can develop. These patients have good mobility of the hip due to instability and they do not have arthritic pain; the source of the pain is the co-existent synovitis and muscle pain. Anteroposterior pelvic graphs are essential to evaluate pelvic structures and obliquity. Spinal deformity is assessed using standing whole spine or lumbar-only radiographs. These are important to evaluate pelvic inclination since many of these patients present with increased lumbar lordosis with or without scoliosis, which is important for acetabular component anteversion. Existing lumbar deformities are structural and they rarely respond to the reconstruction of hip joint position. Patients presenting with previously-operated hips might have more severe femoral site deformities. Berry has classified these deformities with suggested treatment approaches.[8]

Careful pre-operative templating with more than one prosthesis design is essential to determine which femorol templating design will give the best result. Lateral templating is also important since proximal femoral deformity may prevent straightforward insertion of the stem. In unilateral cases, the contralateral side is used to choose the appropriate hip rotation centre; in bilateral cases we use Ranawat’s triangle to determine the centre of rotation[9] (Fig. 3). The required shortening is then to be determined. The level of the lesser trochanter is useful, but is not a flawless method; all measurements should be judged against the clinical picture, because pelvic and lumbar deformities, as well as the available femur below the lesser trochanter, may confuse radiographic measuring from a short pelvic view. Various authors have suggested routine CT imaging as a part of pre-operative evaluation.[4,6]

Gait analysis

Usually the amount of pain and existing contractures determine the gait pattern. Our study on gait analysis demonstrated that temporospatial parameters are disturbed in highly dislocated hips with reduced cadence, single support, stride length, step length and walking speed.[10] Clinical presentation of bilateral cases is less severe due to relatively proportional lower limb length despite overt instability.

Surgical technique

When the deformity is not severe in Hartofilakidis type A and B hips, a variety of common approaches are appropriate for DDH reconstruction. However, it would not be beneficial to use a mini-incision option in type C cases where subtrochanteric osteotomy is required. Generally, anterolateral and posterolateral approaches are adequate for both pelvic and femoral exposure. The supine position of the patient on the table facilitates acetabular component positioning and evaluation of leg length, while the lateral decubitus position is advantageous for better visualisation and handling of pelvic structures posterior to the acetabulum.

A percutaneous adductor tenotomy is recommended in the supine position before the patient is turned to the lateral decubitus position. After the skin incision, the gluteus maximus tendon and the intermuscular septum should be released from their insertion on the linea aspera, exposing the sciatic nerve under visual control as a routine part of the exposure.

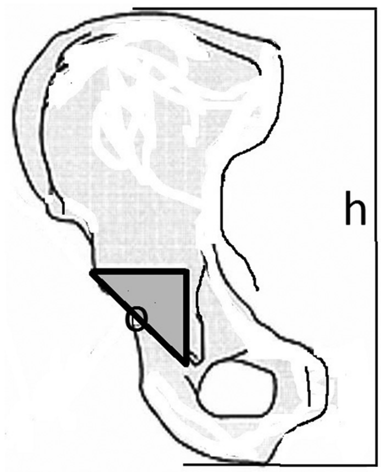


Fig. 3 Ranawat's Triangle: diagram showing Ranawat triangle to determine anatomical hip centre. Height of the isoscheles triangle is one fifth of the measured pelvic height (h).

Although good results have been published regarding cemented reconstructions, there is an increased tendency to perform non-cemented techniques in recent literature.[7,10,11]

On the acetabular side, reconstruction of the high-riding hip is a demanding procedure that requires extensive soft tissue release and visibility of both the false and the true acetabulum, which is usually obscured by osteophytic bone. The hourglass-shaped capsule is followed down to the bone. Careful dissection by tracking the joint capsule is suggested for identification of the true acetabulum. Problems related to acetabular reconstruction are related to the small size, deficient walls and relatively poor bone quality. Acetabular reaming should be directed posteriorly to the ischial bone, where bone stock is more satisfactory. Usually the anterior margin is defective and preserving the integrity of the superior dome is crucial for stability. When bone stock is inadequate for primary superior stability, an autograft is taken from the patient's femoral head and positioned in place with two screws (Fig. 4). A multi-hole acetabular component requires at least two screws.

On the femoral side, the abductors are vital for the stability and functional performance of the reconstructed hip. In this regard, the shortening techniques that preserve the abductor attachment, and other methods that remove the abductors with trochanteric osteotomy are regarded as two distinct approaches. There is substantial agreement among authors on preserving the integrity of the proximal femoral segment, despite several good outcome reports with trochanteric osteotomy and re-attachment.[10,12,13]

The femoral canal should always be prepared before subtrochanteric osteotomy, to take advantage of the easier handling of the bone in one piece. As the femur is also dysplastic, careful and precise reaming and broaching are crucial. With trial implants in place, the distance between the centre of the acetabular implant and the centre of the trial femoral head is

a) b) c)

Fig. 4 Demonstration of the author's preferred technique of anatomical reconstruction with subtrochanteric osteotomy and uni-cortical plate fixation.

measured under moderate traction of the leg. A distance of 3 cm should subtracted from this measurement, since this is the maximum acute stretching distance that the sciatic nerve and femoral artery can tolerate. Two short oblique osteotomies are made in the femur, in the subtrochanteric region below the projected porous coated area of the femoral implant. The trochanteric attachments of the gluteus medius and gluteus minimus should be preserved, as well as the tensor fascia lata, rectus femoris and vastus lateralis in order to protect the blood supply to the proximal fragment. In cases where an iliopsoas release is required due to excessive tension, it must be performed over the pelvic brim at the musclo-tendinous junction. Our preferred femoral implant has two different distal stem diameters for each proximal metaphyseal size, providing better adjustment and fixation distal to the osteotomy. Rotational stability is achieved with the oblique osteotomy surfaces and unicortical screws through a small fragment (3.5 mm) AO plate (Fig. 4). The extracted femoral head is morcellised and grafted around the osteotomy. Controversy exists on the type of subtrochanteric osteotomy and prosthetic femoral implant. Transverse, oblique and step-cut osteotomies are all performed with success when special requirements are necessary.[13-15]

Special rehabilitative measures should be followed during the course of osteotomy healing. Patients are kept on crutches with weight-bearing as tolerated until radiological consolidation, which usually requires between six and 12 weeks. From the early post-operative period, active flexion up to 90° is encouraged to obtain a good range of motion. Active abductor strengthening is done with the patient lying on the contralateral side. A near-to-normal abductor strength is mandatory for limp-free walking.

Discussion

There are several critical issues to deal with when obtaining a successful and long-lasting total hip arthroplasty in this population. It is critical to evaluate patients thoroughly before the operation in order to achieve a totally normal limb function with equal length legs. The surgeon's responsibility is to provide the best possible result with a realistic approach, resulting in a stable, functioning and pain-free hip.

A highly-dislocated hip presents unique problems, such as weak abductors, insufficient bone stock and associated joint problems. Pelvic obliquity, scoliosis and lordosis of the spine, valgus and rotational deformity of the ipsilateral knee, and adaptive deformity of the ipsilateral foot may not be fully reversible. Earlier operations in a patient's history may have further damaged the abductors and pelvic muscles. Usually, existing contractures of the hip capsule and pelvitrochanteric muscles are correctible by surgical release.

Anatomic acetabular reconstruction at the level of the true acetabulum with an uncemented implant has demonstrated good results, and is encouraged. Augmentation of the fixation with extra screws is usually required. Autografting is preferred over allowing superior migration in the acetabular component position to achieve better cup coverage. Wear and the long-term outcome are sensitive to acetabular position.[16,17] Medialisation of the cup is encouraged, but a residual high hip centre gives poorer results.[18]

On the femoral side, cemented *versus* cementless component selection can be judged based on patient age, bone quality and the bony anatomy. In most cases, cementless fixation is preferred for a better outcome.[4,7,10] Anteversion is no longer a problem when subtrochanteric osteotomy is performed, and the femoral stem can be adjusted for the best position on the proximal fragment. In extreme conditions of distorted anatomy, special implant designs such as cone prostheses and modular uncemented stems simplify the management of excessive anatomical deformity or canal tightness.

Some authors prefer step-cut osteotomy to avoid the need for additional plate fixation.[12,19] The distal fixation provided with the Wagner-type prosthesis, and its ability to adopt any rotational position due to the cylindrical stem anatomy, is reported as a unique feature. However, once an osteotomy is performed, rotation of the proximal part is free to occur according to the stability of the reconstructed hip. Hence, equally good results are reported with the Zweymüller prosthesis, characterised by a rectangular-shaped cross-section.[20] A few cases are reported with different reconstruction techniques, such as progressive reduction without osteotomy in two stages or distal femoral shortening and simultaneous correction of the knee valgus deformity.[21]

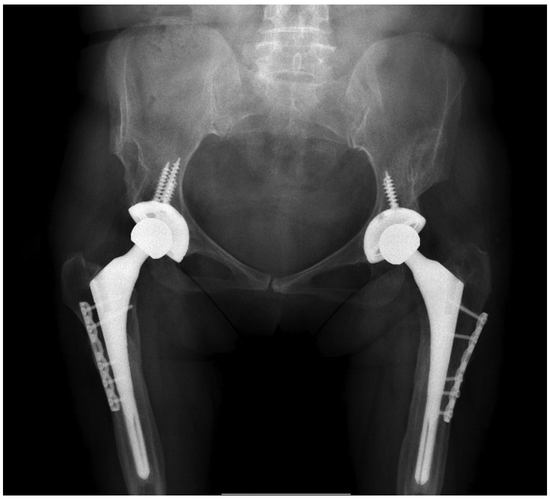
The advantages and disadvantages of the many bearing surface options in total hip arthroplasty are under investigation; the most appropriate choice should be individualised to each patient. Following the wide-ranging use of metal-on-metal surfaces which have demonstrated local soft tissue reactions and hypersensitivity to metal-on-metal bearings, such bearings are best avoided.[4] Possibly related to their favourable wear properties, ceramic bearings present an excellent choice for selected patients in future. However, component fracture and squeaking also need to be considered. Researchers found that patients with squeaking and fracture were more likely to have had acetabular components placed outside the acceptable range of anteversion and abduction. Parvizi et al demonstrated that lateral acetabular component positioning and short head length may increase the risk in younger patients.[22] Highly cross-linked polyethylene (HXLPE) bearing surface data is more promising and appear to be relatively insensitive to head size and component positioning in terms of wear rate. However, HXLPE is not immune from sensitivity to inadequate component positions; it may crack at the locking rim in case of edge loading. Therefore, the surgeon's responsibility is to emphasise the position of the components both individually and relative to each other in every circumstance.

Considering the amount of possible lengthening, there are no definitive guidelines. Patients tend to place great importance on equal limb lengths. In extreme conditions, excessive lengthening may risk sciatic nerve palsy. For safety, the general consensus is to avoid lengthening by more than 3 cm. Intra-operative electrophysiological monitoring has been developed to provide sciatic nerve monitoring but is not always available. Adequate exposure of the sciatic nerve and finger control by palpation is usually the most feasible; the nerve should not be under tension and should give way with a gentle finger push. The intra-operative wake-up test is useful and generally reserved for cases where nerve conduction is suspicious.[23]

Subtrochanteric osteotomy requires adapted, graduated post-operative rehabilitation protocols unique to these patients, with weight-bearing as tolerated with two crutches for six to 12 weeks. The dislocation risk is relatively high due to extensive soft tissue release during surgery. Weight-bearing assisted by two crutches is required until consolidation of the osteotomy which usually occurs around the third month post-surgery.

Gait analysis has revealed that following hip reconstruction, the pattern and timing of the gait in terms of flexion and extension of the hip resulted in a nearly normal curve (Fig. 5). However, in most studies, the knee was kept in flexion with insufficient extension during mid-stance. The most dramatic improvement was in the ankle joint; following the correction of limb length discrepancy the ankle kinematics improved to normal. Pain is relieved and the activities of daily living improve in patients with high-riding DDH, but they are still behind the normal population average. Nevertheless, the results can be nearly as satisfactory as those in patients who undergo a total hip arthroplasty for primary osteoarthritis.[24]

a)



b)

Fig. 5 A 54-year-old female patient presenting with bilateral deformity. She had received bilateral hip prosthesis nine months apart; 11 years after the index procedure she has maintained good function and a stable posture.

Surgical complications

Complications are relatively frequent in this group of patients when compared with total hip arthroplasty for any other reason. The cause is multi-factorial, including abnormal anatomy, the large soft tissue release, osteotomy and abrupt lengthening of the extremity. Sciatic and femoral nerve palsies are up to ten times more frequent.[6] Dislocations are reported between 2.9% and 11%.[4] Non-union at the subtrochanteric osteotomy site may occur, and is typically related to inadequate fixation where rotational stability is a major concern.

Cemented techniques have been reported to provide good results both on the acetabular and femoral sides.[4,11] However, these were of a mixed series, where simple dysplastic cases were in the majority. The greatest concern arises when shortening is indicated at surgery; cement extrusion is possible at the site of osteotomy leading to non-union.[25] On the acetabular side, regarding the relatively inferior results of cemented cups, attention is drawn to all uncemented techniques worldwide.[4,10] Generally a two- to three-fold increase in revision rates in highly dislocated cases is reported as opposed to that in primary arthritis (Table 1).[4]

Table 1. Substantial deformity may be observed due to previous hip operations in childhood

	Deformities of proximal femur due to previous operations
Site of deformity	Greater trochanter Intracapsular (Resectable during THA) Metaphysis Diaphysis
Geometry of deformity	Angular (varus, valgus, flexion, extension) Translational (AP or LAT plane) Torsional (excessive anteversion, retroversion) Abnormality of size (large or narrow canal diameter)

Between 1998 and 2006, 81 patients with 95 hips who had high dislocation of the hip underwent anatomical reconstruction with a total hip arthroplasty and subtrochanteric osteotomy in our institution. In this consecutive series, a proximally hydroxyapatite-(HA) coated cementless total hip implant with HA-coated acetabular component and HXLPE insert were used in all patients. Surgical protocol consisted of an extensive soft tissue release with total capsulectomy, anatomical restoration of the hip centre, subtrochanteric short oblique osteotomy and uni-cortical plate fixation for rotational control (Fig. 6). Patients were followed up for an average of five years (between two and ten years). All the patients showed dramatic improvement after the index procedure and during the follow-up period. The Hospital for Special Surgery Hip Score improved from

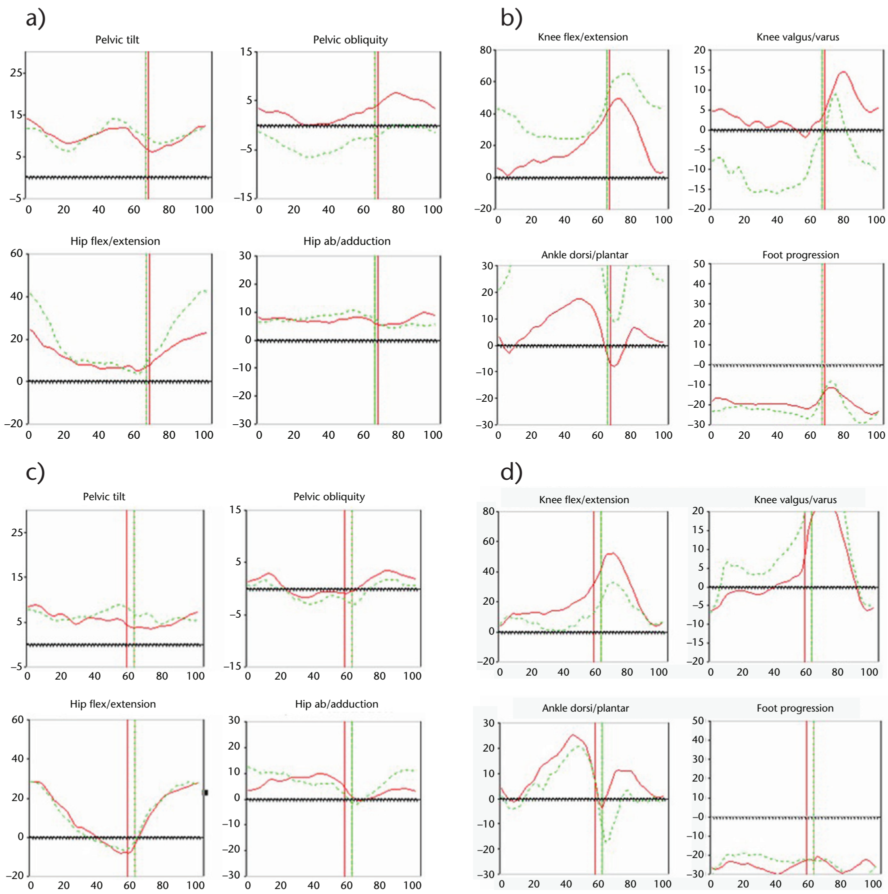


Fig. 6 Joint kinematics from hip, knee and ankle joints. The positive values of the vertical axis correspond to the flexion and adduction in the hip, flexion and varus in the knee, and dorsiflexion and in-toeing of the ankle. A continuous line in the graphs indicates a normal average, and dotted lines indicate patient status. a), b): pre-operative gait analysis; c), d): post-operative gait analysis.

Table 2. Previous studies on high dislocated hip dysplasia treated with total hip arthroplasty and subtrochanteric osteotomy

Study	No. of patients	Osteotomy type	Femoral stem	Follow-up	Complications related to osteotomy	Revisions
Charity et al[25]	18	Transverse + 3.5 mm plate	Exeter cemented	114 months	1 nonunion	3 acetabula, 1 femur
Akiyama et al[27]	15	Transverse + cortical graft		3 to 10 years	3 nonunion	None
Sener et al[12]	23	Step-cut	Zimmer Anatomic		2 nonunions, 2 grafting	None
Krych et al[13]	28	Transverse	Extensive porous-coated, modular	4.8 years	2 nonunions, 4 dislocations	1 acetabulum
Erdemli et al[29]	21	19 Transverse, 3 step-cut	Non-specific	5 years	1 nonunion,	None
Koulouvaris et al[22]	24	Distal femoral	Custom-made cementless	55.7 months	1 nonunion	None
Masonis et al[30]	21	Transverse	10 cemented, 11 uncemented	5.8 years	2 nonunions	3 femoral revisions, 2 acetabular revisions
Toğrul et al[28]	21	Transverse with bone pegs	Cementless	41.2 months	2 dislocations	1 head exchange

a mean of 20.41 pre-operatively to a mean of 34.39 at follow-up. There were two nonunions at the osteotomy site which required grafting, one of which needed required femoral stem revision. Two cups were revised due to aseptic loosening. The Kaplan–Meier survival rate, when failure was defined as removal of the components for any reason, was 98.8% at five years. The authors, having used different techniques and implants, reported considerable functional improvement but with variable success rates and relatively high complications (Table 2). Supplementary Videos 1 and 2 (http://www.efortopenreviews.org/content/1/3/65.figures-only) demonstrate patients presenting with high dislocated hips on gait analysis at pre- and post-operative follow-up, six months after reconstruction with total hip arthroplasty.

Conclusions

Developmental dysplasia of the hip is a major hip pathology leading to pain, arthritis and hip surgery in young patients. In severe cases, a subtrochanteric osteotomy allows for correction of femoral anteversion, assists adaptation of the femoral stem to the distorted proximal femoral metaphysis and overcomes excessive lengthening. Anatomical reconstruction of the hip is required for maintenance of function during the long follow-up periods, with good clinical and radiographic outcomes. It is essential to remember that the best practice requires careful patient selection and the use of appropriate techniques.

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CONFLICT OF INTEREST

None declared

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