Total Hip Replacement in Developmental Dysplasia of the Hip: Pitfalls and Challenges

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Abstract

Introduction: Surgical treatment methods for developmental dysplasia of the hip (DDH) in the elderly patients contain pelvic or periacetabular osteotomy and hip arthroplasty. Total hip arthroplasty (THA) is the last and definitive surgical treatment modality for the end stage developmental dysplasia of the hip.

Deformity classification and reconstruction: Crowe classification system describes the degree of dysplasia and gives information about the reconstruction procedure with hip arthroplasty. Classification is based on the magnitude of proximal femoral migration relative to the acetabulum. Acetabular component must be implanted to the true acetabulum for the optimal range of motion and stability of the reconstructed hip. The femoral component must be placed in neutral or slight anteversion but narrow femoral canal can be a problem for the reconstruction of femur.

Conclusion—key results: The results of total hip arthroplasty in developmental dysplasia of the hip have been satisfactory for stability, mobility, and pain relief. The survivorship of cemented arthroplasty in dysplastic hips is inferior because of the young age of the patients and the complexity of the procedures. Early and midterm results of cementless hip arthroplasty are better. Most important complications after the surgery are dislocation of the reconstructed hip and sciatic nerve injury.

Keywords: hip, arthroplasty, developmental dysplasia

1. Introduction

Hip arthroplasty is the end stage treatment method for developmental dysplasia of the hip (DDH). Pelvic and femoral osteotomies are the first option for surgical treatment. Before performing osteotomies, cartilage space in the hip joint must be determined. It must be verified with X-rays. In the long-term follow-up after pelvic or femoral osteotomies, degenerative changes occur in the hip joint. Also, hip arthroplasty is the last stage treatment modality after osteotomies around hip joint.

Hip arthroplasty for developmental dysplasia of the hip is technically complex surgical procedure because of the anatomical changes of acetabulum and proximal part of the femur. Soft tissue contractures and laxity can be present as a result of the acetabular and proximal femoral anatomical differences.

Patients with dysplasia require arthroplasty in younger age than the others with osteoarthritis. For this reason, implant selection is an important issue. Bearing surfaces alternative to metal on polyethylene should be preferred in this young patient population.

2. Anatomical differences in developmental dysplasia of the hip

2.1. Acetabular abnormalities

An acetabulum with dysplasia can be shallow, narrow, and lateralized. Increased anteversion and deficiency of the anterior and superior walls of acetabulum are changes expected to be seen in these patients [1]. The width of acetabulum remains same, but there is an increase in length and decrease in depth [2, 3]. As a result of these deformities, the coverage of the femoral head by the acetabulum has deficiency anteriorly, laterally, and superiorly. Completely dislocated hips have a false acetabulum on ilium with joint capsule. True acetabulum is hypoplastic and invaded with adipose tissue.

2.2. Femoral abnormalities

The dysplastic femur has a small femoral head. Femoral neck anteversion has increased. Generally, femoral neck is shortened with an increased neck-shaft angle [3]. There can be posterior displacement of trochanter major and a narrow femoral canal can be seen [1]. Narrowing of medullary canal around the level of the lesser trochanter is evident in Crowe IV DDH [4].

2.3. Soft tissue abnormalities

The abductor muscles orientation becomes transverse. Hypertrophies can be seen in psoas tendon and hip capsule. The hamstrings, adductors, and rectus femoris muscles shorten. Also, ligamentum teres and labral hypertrophies occur. For patients with unilateral DDH, the sciatic nerve lies close to the ischium and ilium but far from the femur of DDH when compared to healthy side. Sciatic nerve becomes shorter in the affected side, and it can be injured by posterolateral approach [5].

3. Classification of developmental dysplasia of the hip

There are several classification systems for developmental dysplasia of hip. Most popular ones are that were defined by Crowe and Hartofilakidis [6, 7]. There are three grades according to Hartofilakidis classification. The femoral head is covered within the true acetabulum in the first grade. In the second grade, femoral head has an articulation with the false acetabulum, and there is a contact between inferior lip of the false acetabulum and superior lip of the true acetabulum. This type is also called low dislocation. In the third grade, the femoral head is outside the true or the false acetabulum, and there is no articulation between femoral head and acetabulum. It is called high dislocation [7].

Crowe classification is a radiological classification based on proximal migration of the femoral head. There are four categories in this classification. The migration is calculated by measuring the vertical distance between the inter-teardrop line and the medial head-neck junction of hip. The stage of the subluxation is determined by the ratio of this distance to the vertical diameter of the opposite femoral head. If this ratio is less than 50% type 1, between 50% and 75% type II, between 75% and 100% type III, and greater than 100% subluxation type IV [6] (**Figure 1**).

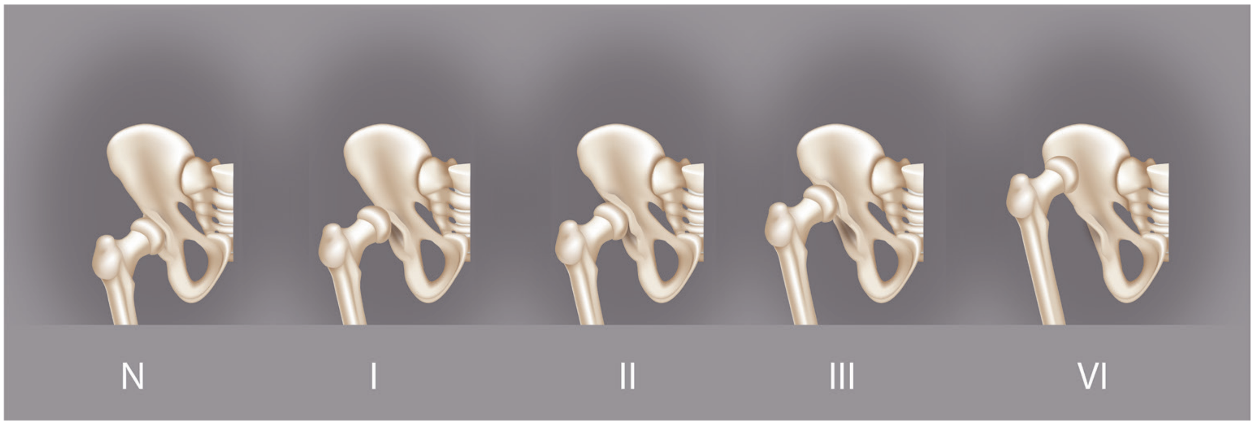

Figure 1. Crowe classification for developmental dysplasia of the hip.

4. Preoperative evaluation

Total hip arthroplasty (THA) is recommended for patients with end-stage disease who have pain and restriction in activities of daily living. Hip range of motion must be evaluated. Limb length inequality of the effected extremity must be measured. Anteroposterior views of the pelvis and hip radiographs should be taken. Lateral views of the hip and Judet views can be helpful to determine the acetabular bone stock. CT scan can be useful to evaluate acetabular bone stock and femoral version [8].

Bone stock of the acetabulum is the first important issue for preoperative planning. If there is enough acetabular bone stock for implantation of the acetabular cup, it will facilitate the surgical process. But if there is not enough bone stock, then bone grafting and reconstruction systems for hip arthroplasty must be considered.

Anteversion of the femoral neck, femoral stenosis, and limb shortening are the main problems that can be faced. If the rotation of the affected extremity is advanced, corrective osteotomy can be planned [9, 10]. Femoral bowing is another difficulty in adaptation of the femoral component. Templating helps to select the ideal femoral component size.

5. Surgical approaches

Hip arthroplasty can be performed through anterolateral, anterior, and posterolateral approach. But extensile exposures are needed when there is difficulty in reaching the bone structures. Transtrochanteric approach is the one that can be used for this condition but nonunion is the most important complication. When femoral shortening is needed, a transfemoral approach and subtrochanteric osteotomy can be considered. There is an increased risk of sciatic nerve injury if leg lengthening is over 3–4 cm [11]. Femoral shortening osteotomy can be performed to avoid sciatic nerve injury [9].

6. Acetabular reconstruction

The aim of the acetabular reconstruction is to place the acetabular component to true acetabulum and to provide the normal biomechanical properties of the hip with normal hip center of rotation. Another important issue is the coverage of the acetabular cup with the acetabular bone. If there is not enough support with the bone, there can be increased stresses at the bone-implant (or bone-cement) interface, and mechanical failure can occur in the early period. For this reason, acetabular cup coverage by the natural bone must be done as much as possible. If acetabular cup coverage is not provided, alternative reconstructive techniques should be performed. The methods of reconstruction are discussed according to Crowe classification.

6.1. Crowe I hips (dysplasia)

These types of dysplastic hips have a minimal acetabular bony deformity. Reconstruction of the acetabulum can be done with the standard acetabular component. The component can be medialized to increase coverage of the implant by the natural bone. Good clinical results may be achieved using standard prosthesis stem sizes and press-fit acetabular component [12]. But small diameter femoral heads can be used for this reason that kinds of small implants must be ready to use in the operating room. Large femoral heads can be used when stability of acetabular component is achieved. Short-term results of large head metal-on-metal total hip arthroplasty in young and active patients with developmental dysplasia of the hip are similar to conventional THA [13]. Resurfacing hip arthroplasty is an option for the surgical treatment. There are several complications that can be seen like femoral neck fractures. But fixation of the acetabular component without adjuvant fixation can be achieved without complete acetabular coverage of the acetabular component [14].

6.2. Crowe II and III hips (low dislocation)

There is bone deficiency in the lateral part of the acetabulum. There is less bone support for the acetabular component. There are several surgical techniques to increase the coverage of the acetabular component. The medial wall of the acetabulum can be reamed deeper, so coverage of the acetabular component can be increased. But if the coverage of the cup is not sufficient by this method, acetabular augmentation, reconstruction of the acetabulum in a superior location, or acetabular reinforcement rings are the other alternatives to provide coverage [15].

Bone grafts and cement are used for acetabular augmentation in the presence of superolateral acetabular defect. Allografts can be used, but patient's original femoral head is generally a good option. With this technique, normal hip center of rotation can be achieved with strong superolateral acetabular bone stock. A total of 60–70% coverage of the cementless acetabular cups can be acceptable [16, 17]. Long-term results of the bone stock of the acetabulum that was reconstructed using femoral head as autograft are favorable [18]. But if the amount of the acetabular component that is covered by graft is not large, there is a risk of graft resorption and collapse [19].

The other alternative technique is reconstruction of the acetabulum in a superior location which is called high hip center. The acetabular component is covered more with bone, and this technique facilitates biological fixation, and generally, there is no need for bone grafts. Main disadvantage of this technique is the need for small acetabular component with small femoral head which restricts range of motion of hip with abnormal hip biomechanics [20]. Midterm results of cementless acetabular component hip arthroplasty with high hip center are satisfactory with low rates of revision surgery [21].

Another technique is medialization of the acetabular component by over reaming the medial wall of the acetabulum. This technique was described first by Dunn and Hess [9]. It is also called acetabuloplasty. Medialization of the hip center of rotation increases coverage of the acetabular component and decreases joint reactive forces. Cup medialization has a compensatory effect on the femoral offset of the hip with less femoral antetorsion [22]. The only disadvantage of this method is the loss of bone stock of the medial acetabulum. The rate of medial protrusion of <60% is recommended for acceptable clinical and radiographic results [23].

The last technique is to use acetabular reinforcement rings for deficient acetabular bone. Ring is implanted to maximize host bone contact. Then, polyethylene cup is cemented in appropriate position for hip biomechanics. Reinforcement rings provide predictable good long-term results [24, 25].

6.3. Crowe IV hips (high dislocation)

In Crowe IV hips, the acetabulum is hypoplastic, but the superior rim of the acetabulum is less eroded than Crowe II and III hips, and bone stock is more than the Crowe II and III hips. Acetabular component can be placed to the anatomic hip center. But small-sized acetabular components can be used because of the hypoplastic acetabulum [26].

7. Femoral reconstruction

There are several deformities that can be seen in the femoral part of hip joint. There is an increased anteversion and valgus deformity. The medullar canal is generally narrower than normal medullar canal. Anterior-posterior diameter of the canal is more extensive than the medial-lateral diameter. The great trochanter can be placed posteriorly than normal hip.

7.1. Crowe I and II hips

In Crowe type I and type II dysplasias, femoral length is not a problem for reconstruction. Generally, there is no need for femoral osteotomy. Small diameter cemented or cementless stems can be used because of the narrower femoral medullar canal. Proximally coated femoral components are good options for the femoral reconstruction without osteotomy. Hip center of rotation can be changed in the reconstruction of acetabular part. For this reason, anteversion of the femoral component is an important issue for the hip stability. Placement of the femoral component is recommended in neutral or slight anteversion. Anteversion of the femoral neck can be significant in some hips, so femoral component anteversion must be aligned to the axis of the knee joint.

7.2. Crowe III and IV hips

After the center of hip rotation is configured in the true acetabulum, reduction of the hip joint in Crowe type III and IV hips is difficult because of the femoral length. Isolated soft tissue release is not enough for the reduction. For this reason, femoral osteotomies should be done. If the reduction of the hip joint is maintained after the soft tissue release, resulting in leg lengthening of more than 4 cm, then sciatic nerve injury may occur [27, 28].

There are two kinds of femoral osteotomies that can be performed in total hip arthroplasty for Crowe Types III and IV hips. First one is trochanteric osteotomy with proximal femoral shortening. Trochanteric osteotomy provides visualization of femur and acetabulum and preserves abductor mechanism with low risk of dislocation [29]. But risk of nonunion of great trochan-

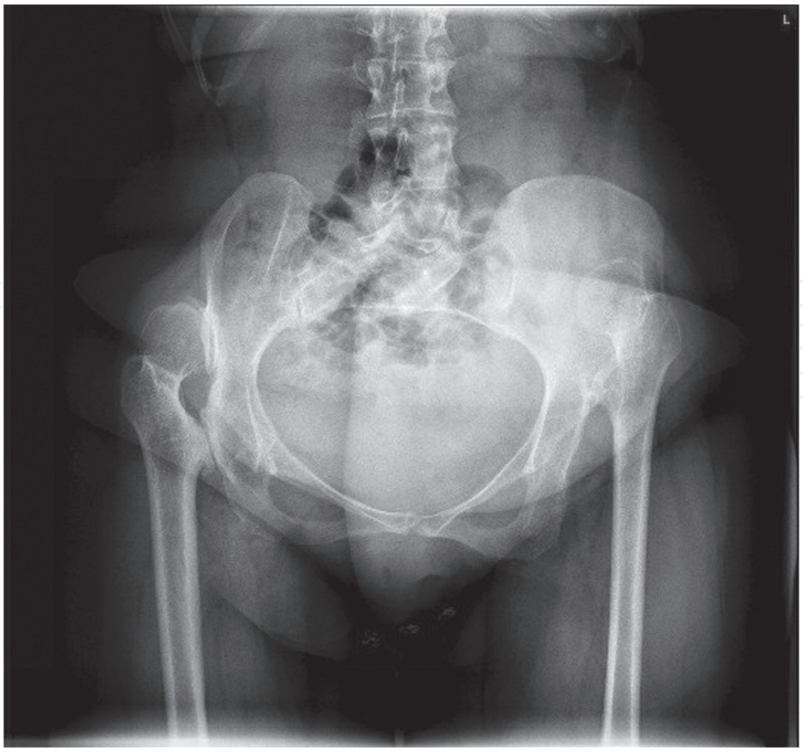

Figure 2. Bilateral Crowe IV developmental dysplasia of the hip. Both acetabula have bone deficiency with narrow femoral canal.

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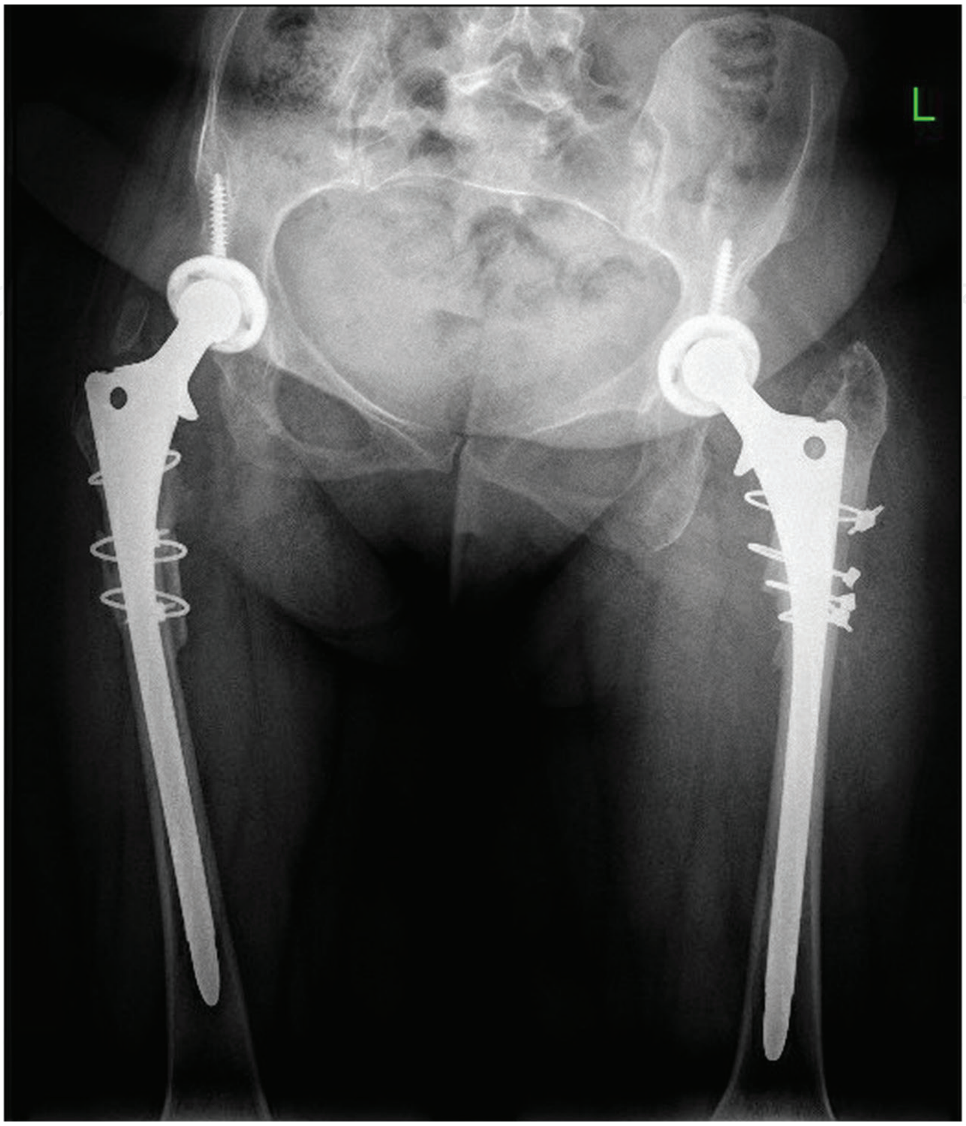

Figure 3. Postoperative radiograph of the pelvis showing bilateral reconstruction. Both acetabular reconstructions are done in a higher position than the true acetabulum because of the acetabular bone deficiency. Bilateral femoral shortening has been performed with usage of resected bone as auto graft.

ter is much with this technique [30, 31]. Subtrochanteric osteotomy preserves the metaphyseal region and has an advantage of correcting the rotational abnormalities with femoral shortening [32, 33]. After subtrochanteric femoral shortening, osteotomy noncemented femoral component can be used but a cemented DDH specific stem is preferable.

Subtrochanteric osteotomy is performed through a lateral approach than a transverse osteotomy is created in the subtrochanteric region. A femoral component is inserted to the proximal part of the osteotomy; then, hip is reduced. At this time, the amount of the femoral shortening can be calculated, and second cut is performed on distal part. Then, distal part of the femoral component is inserted to the distal fragment with adjusting anteversion. Prophylactic cerclage wiring of the fragments can prevent fractures. The resected portion of femur can be used as auto graft over the osteotomy line (**Figures 2** and **3**). Instead of a transverse osteotomy, a chevron-shaped osteotomy which was defined by Becker and Gustillo can be performed for more rotational stability [34].

In some cases, there can be an impingement of the trochanter on the pelvis in abduction or on the posterior acetabulum in external rotation. To solve impingement in abduction, trochanter is osteotomized and reattached distally. Trochanter is osteotomized and reattached laterally for the impingement in external rotation.

8. Bearing surfaces

Generally, there are three types of bearing surface alternatives for hip arthroplasty. Metal on polyethylene is the one that is used mostly. Polyethylene wear is the important issue for osteolysis and revision surgery. Most of the patients with DDH have to be performed hip arthroplasty in younger ages than the primary osteoarthritis. For this reason, other bearing surface alternatives must be chosen for the younger patients. Metal on metal bearing surface has an advantage of larger head sizes with small acetabular components. Larger head sizes provide more range of motion [35, 36]. Adverse allergic reactions and increased ion concentrations in the blood are the main unknown circumstances [37]. Ceramic on ceramic bearing surfaces has low friction but component fracture, development of noise, and less implant size options are the restrictive situations.

9. Total hip replacement in developmental dysplasia of the hip—pitfalls and challenges

9.1. Acetabular part

Cemented acetabular components can be used for the reconstruction of the acetabulum with the acetabular wall defects. Providing appropriate position of the component can be difficult because of the acetabular bone defects. Inappropriate placement of the acetabular cup causes decreased range of motion, less stability, and hip dislocation. Aseptic loosening is the main problem as a result of inappropriate placement of the acetabular cup in the long-term follow-up period. Cemented acetabular components have variable results in the literature. Survival ratio of the acetabular component was found 96% and 91% at 15 years with excellent long-term clinical and radiographic survivorship for acetabular dysplasia [38]. In another study with mean follow-up period of 15.7 year, the survival of the cemented acetabular component was 78%. The main reason of revision surgery was aseptic loosening with ratio of 88.3%. Higher rate of failure of the acetabular component was determined with increasing severity of hip dysplasia according to Crowe and Hartofilakidis classification [39]. Proximal migration of the hip center of rotation and nonanatomic placement of the acetabular component are the main reasons for aseptic loosening of the cemented acetabular component [40]. Nowadays, cemented acetabular reconstruction is not the first line treatment modality because of high revision rates [41, 42].

Coverage ratio of noncemented cups is the main important issue for the survival of the implant. For this reason, we must provide as much as possible surface coverage of the

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acetabular cup by acetabulum. But acetabular wall fracture can occur while reaming of the acetabulum. Reconstruction plates must be ready in the operating room. Noncemented acetabular components with grafts have same survival rates like the cemented acetabular components, with revision rates of 0–5% [43, 44]. The 20-year survivorship free from acetabular revision was 66% for noncemented acetabular components with femoral head as autograft [45]. In another study, 57% of the acetabular components underwent revision at a mean of 14.6 years because of osteolysis [46]. Twenty percent of the superolateral aspect of the acetabular cup could be left uncovered to prevent the failure risk [47] but there is no exact data about the amount of adequate acetabular cup coverage. Li et al reported results of the hip arthroplasty with more than 30% lateral uncoverage of noncemented acetabular components. There were no prosthesis revision and loosening during the mean 4.8 years follow-up [48]. Tikhilov et al. recommend acetabular component fixation without screws with moderate uncoverage within 25% but they offer two-screw fixation with significant uncoverage to 35% [49].

High hip center is another reconstruction option. The new acetabulum in the high hip center does not have strong osseous structures like true acetabulum. Reaming of the new acetabulum for the acetabular component can be resulted as a perforation of the bone. Superior wall of the acetabulum is not so strong, and acetabular cup stabilization cannot be sufficient. Acetabular cup stabilization can be provided with extra screws. These extra screws can cause neurovascular injury. In some cases, the new acetabulum can be formed in a higher position than the true acetabulum because of the acetabular bone deficiency (**Figure 2**). There are several studies that showed good results with cemented and noncemented acetabular components [21, 50, 51]. Results of a study that was compared the survivorship of the components for anatomical or high-cup placement; 100% in the anatomical placement and 97% for high hip center group [52]. Higher loosening and revision rates for both femoral and acetabular components have been reported with cemented acetabular cups for high hip center [40, 53]. There is a correlation between lateral displacement of the hip center and higher rates of component loosening [40].

Medialization of the acetabular cup can provide more surface coverage of the acetabular component by acetabular bone. To achieve a good stabilization, acetabular component can be 1 size larger than the acetabular reamer size. While impacting the acetabular component, there is a risk for acetabular fracture. If a fracture occurs, we must check the stability of the acetabular component. If the stability of the acetabular component is insufficient, stabilization must be maintained with extra acetabular cup screws. Medialization of the acetabular component by medial wall reaming has been reported low revision rates with both cemented and noncemented components [7, 54]. Medial wall defect of 25% of the acetabular area is recommended [54]. But in another study, higher loosening rates of the cemented components have been determined [55].

9.2. Femoral part

Narrower femoral canal in DDH is the main problem for femoral component. Cemented femoral components have an advantage of low fracture risk during the fixation. Cement mantle must cover one third of the cross-sectional area of the femoral canal. Distal centralizer must be used for the correct placement of the femoral component. Appropriate anteversion, valgus, and varus position of the femoral component must be provided in the period of cement polymerization. Modular or cemented stem should be used for extreme anteversion. Cemented femoral components have good long-term follow-up. Femoral component revision rates are 3–10% according to the literature [42, 56]. Cemented femoral component revision rates are lower than the cemented acetabular component. A total of 28 patients (35 hips) who underwent a cemented THA for DDH had been reviewed retrospectively. The overall revision rate was found 20%, and femoral revision rate was found 9% [57].

Noncemented femoral components are more popular nowadays. There is a risk of femur fracture while rasping the femoral canal and implantation of the noncemented femoral components. If a fracture occurs in that period, fixation must be achieved with cerclage wires or with a long femoral stem. Noncemented femoral component survival seems good. In a study of 15 patients with 17 hips, 57% underwent revision of the acetabular component at a mean of 14.6 years because of osteolysis. But no patient underwent revision because of femoral component loosening [46]. In another study with 106 patients with DDH, 18 acetabular revisions had been performed but there was no femoral component revision for any reason with mean follow-up period of 13.5 years [58]. Short-stem implants can be used for the reconstruction of the hip. Results of the hip arthroplasty with the short-stem implants in patients with DDH have good clinical outcome like primary osteoarthritis [59]. This type of implants can be used for lower grades of DDH.

Fixation of the subtrochanteric osteotomy with noncemented femoral components has favorable results. After the osteotomy and resection of the femoral segment, there can be inequality between proximal part cross-sectional area of the femoral canal and distal part cross-sectional area of the femoral canal. Long femoral stems improve stability. In some cases, modular femoral stems can be useful. Resected portion of femur can be used as auto graft over the osteotomy line. Also, this auto graft with cerclage wires has an additional support for stability (**Figure 3**). Crowe IV hips treated with subtrochanteric osteotomy using noncemented components show excellent healing rates [11, 60, 61]. But Park et al. reported three femoral nonunions on 24 hip arthroplasties with subtrochanteric shortening osteotomy [62].

There are several studies that compare THA outcomes in dysplastic and nondysplastic patients. As a result of a study which compares the dysplastic and nondysplastic hips, no significant difference was detected in Oxford Hip Score and revision rates between the two groups [63]. However, revision rates are more in dysplastic hips than in non-dysplastic hips in long-term follow-up [64]. Hip arthroplasty for DDH is complex surgery, and the cost of this procedure is more than a hip arthroplasty for primary osteoarthritis. Increased degree of dysplasia according to Crowe classification has been associated with higher costs [65].

10. Complications

Infection is an important complication that can occur after hip arthroplasty. The possibility of infection is increased in DDH. Surgical procedure time, exposure length, and use of more implants can be among the reasons. Nerve palsy, dislocation, and mechanical failure can be seen as a result of improper surgical technique and implant selection. Early loosening of the acetabular component, limping, and limb-length discrepancy can be seen in the high hip center type of reconstruction. Fracture and dislocation of the cup inside the pelvis are the most important complications for medialization technique. Nonunion of greater trochanter is an important complication after trochanteric osteotomy. Nonunion of the osteotomy site after femoral shortening procedures can be seen.

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