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Surgical Technique

The Capsular Arthroplasty

A Useful But Abandoned Procedure for Young Patients With Developmental Dysplasia of the Hip

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Abstract

Background Codivilla in 1901, Hey Groves in 1926, and Colonna in 1932 described similar capsular arthroplasties—wrapping the capsule around the femoral head and reducing into the true acetabulum—to treat completely dislocated hips in children with dysplastic hips. However, these procedures were associated with relatively high rates of necrosis, joint stiffness, and subsequent revision procedures, and with the introduction of THA, the procedure vanished despite some hips with high functional scores over periods of up to 20 years. Dislocated or subluxated hips nonetheless continue to be seen in adolescents and young adults, and survival curves of THA decrease faster for young patients than for patients older than 60 years. Therefore, joint preservation with capsular arthroplasty may be preferable if function can be restored and complication rates reduced.

Description of Technique We describe a one-stage procedure performed with a surgical hip dislocation and capsular arthroplasty. Various additional joint preservation procedures included relative neck lengthening for improved motion clearance and head size reduction, roof augmentation, and femoral shortening/derotation for containment and congruency.

Methods We retrospectively reviewed nine patients (one male, eight female; age range, 13–25 years) who had such procedures between 1977 and 2010. Function was assessed by the Harris hip score (HHS). Minimum followup was 1 year (median, 2 years; mean, 7.5 years; range, 1–27 years).

Results At latest followup, the mean HHS was 84 (n = 7) (range, 78–94). One patient underwent THA after 27 years. Complications included one deep vein thrombosis and one successfully treated neck fracture.

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Each author certifies that his or her institution approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.
The operations were performed at the institutions of all authors. The study was performed at Schulthess Clinic, Zürich, Switzerland.

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Conclusions Our data in these nine patients suggest capsular arthroplasty performed with a surgical hip dislocation and other appropriate adjunctive procedures is useful to treat dislocated hips in young patients with few complications. It may postpone THA.

Level of Evidence Level IV, therapeutic study. See Instructions for Authors for a complete description of levels of evidence.

Introduction

In 1901, Codivilla [9] first described a technique to treat the older child with a complete congenital dislocation of the hip by wrapping the capsule around the femoral head before reducing it into the deepened true acetabulum. In 1902, an abstract was published for Codivilla's visit to the Hospital for the Ruptured and the Crippled (today the Hospital for Special Surgery) in New York [10]. An Italian version of the technique was published 10 years later [11]. In 1926, Hey Groves described a similar operation [25]. In 1932 and later, Colonna [12–16] reported his capsular arthroplasty technique, which was essentially similar to those described by Codivilla and Hey Groves. Others [1, 8, 17, 20, 23, 32, 36–38, 45] subsequently reported high levels of function after such procedures. Following a group of Colonna's patients, Chung et al. [8], for example, noted "excellent" and "good" Harris hip scores (HHS) in more than 50% of patients after 17 years; they also noted 19% necrosis of the femoral head and 8% joint stiffness, the latter especially in bilateral cases [8]. Pozo et al. [38] found 70% of the 50 hips previously reported on by Trevor [48] had a HHS of more than 80 after 20 years.

Colonna described a two-stage procedure. The first stage was continuous skin traction for 2 to 3 weeks followed by tendon release. The second stage was relocation of the hip. He recommended the procedure for complete dislocations in children between the ages of 3 and 8 years; he did not perform the procedure in patients with subluxated hips or those with teratogenic anomalies such as arthrogryposis. Colonna [16] performed his arthroplasty in a few patients with bilateral dislocations; however, reduced ROM or even stiffness produced more severe limitations than in unilateral cases [8, 38, 41]. Subsequent reports from others described capsular arthroplasty in patients between 1 and 23 years of age [33] or included those with subluxation [48]. The reported rates of osteonecrosis of the femoral head have varied from 0% to 50% [8, 33, 45, 48] when the term epiphysitis is presumed to be synonymous with epiphyseal necrosis but flattening of the femoral head is excluded. Bertrand [2] replaced traction by femoral shortening, but Stans and Coleman [45] showed femoral shortening and derotation at the time of capsular arthroplasty reduced the need for subsequent procedures and, more importantly, the incidence of femoral head necrosis. Secondary operations after capsular arthroplasty were necessary in 18% to 30% [8, 38], mostly to improve the mechanical status of the hip, augment coverage, or treat redislocation of the hip.

With increasing use of ultrasound as an early screening method for developmental dysplasia of the hip (DDH) [24, 29, 39] and appropriate treatment, high dislocation became rare, especially in Western countries. Coincidently, THA became more reliable and today is known as the operation of the century [34]. Both evolutions decreased the demand for joint-preserving techniques such as the capsular arthroplasty: the most recent followup paper on capsular arthroplasty was published in 1999 [4] and the authors concluded they "do not support revival of this now obscure procedure." On the other hand, the survival curves of THA for patients younger than 50 years show a clear drop after 10 years [46]. Schulitz and Griss [41] and Tönnis [47] recommend for patients up to 8 to 9 years open reduction of the femoral head into the primary acetabulum, eventually combined with femoral or acetabular reorientation. When performed at a later age, our own experience revealed increased risk of resubluxation [42]. Therefore, we believe capsular arthroplasty should be reconsidered as an alternative for the remaining group of young patients with decent femoral head cartilage presenting with chronic subluxation or complete dislocation. With simultaneous femoral shortening and newer surgical techniques, osteonecrosis of the femoral head, joint stiffness, and secondary subluxation, which accounted for the majority of failures of capsuloplasty [8, 23, 33, 38, 45], can be reduced.

We describe a modified Codivilla-Hey Groves-Colonna capsular arthroplasty and report the function and radiographic findings and complications in nine hips undergoing this procedure.

Description of Technique

Codivilla [9] and Hey Groves [25] used an anterior approach, similar to the Smith-Petersen approach [44]. Colonna [16] used an anterior transtrochanteric approach and Trevor [48] used a transtrochanteric approach with an Ollier-type incision. Here we describe the results of a modified procedure via a surgical hip dislocation [21]. The surgical hip dislocation provides good exposure of the acetabular cavity and allows for near-circumferential dissection of the capsule from all adherent muscles. However, care must still be taken to avoid trauma to the deep branch of the medial femoral circumflex artery, which is the main blood supply to the femoral head [28]. If necessary, the approach allows for additional relative femoral neck

lengthening and for reduction osteotomy of the femoral head [22]. It can also be easily extended distally to perform intertrochanteric or subtrochanteric osteotomies.

Our indications for capsular arthroplasty were hips in patients from about 10 to 25 years of age with severe chronic subluxation and acetabular cartilage destruction, with secondary acetabulum or with complete low and high dislocation in (1) DDH, (2) neurogenic hips such as in spina bifida, and (3) congenital anomalies such as arthrogryposis. The contraindications for this surgery were (1) severe damage to the hyaline cartilage of the femoral head and/or gross deformity of the head contour because we believe such conditions cause severe joint stiffness; and (2) bilateral congenital dislocations because, in contrast to unilateral dislocation, we believe bilateral dislocations are usually better tolerated for several decades. Alternative techniques may be indicated for the age group 10 years and younger or as a compromise with regard to comorbidities. Isolated iliopsoas transfer has its best indication for dislocation in patients with spina bifida younger than 10 years with strong quadriceps [5]; it may become an additional procedure to capsular arthroplasty in ambulatory cerebral palsy to reduce the risk of redislocation. Schanz-type osteotomies were used in the past for high dislocations from DDH to reduce limp. However, more recent literature discusses the technically demanding surgery of THA in such deformed hips [19]; today, the Schanz osteotomy is still in use for non-ambulatory quadriplegic patients to facilitate nursing [40].

The surgical dislocation technique is described in detail elsewhere [21, 22]. Briefly, the patient was positioned in a lateral decubitus position with the upper leg draped freely. A longitudinal incision was centered over the anterior ⅓ of the greater trochanter. The fascia lata was incised along the anterior border of the gluteus maximus muscle allowing posterior retraction of this muscle. Slight internal rotation of the leg helped to visualize the posterior border of the greater trochanter and the posterior border of the gluteus medius muscle. A trochanteric osteotomy was performed with an oscillating saw, beginning slightly anterior to the trochanteric crest. The mobile portion of the trochanter included the insertion of the gluteus medius and vastus lateralis muscles. The capsule was exposed between the piriformis and gluteus minimus muscle, a step that may be more difficult in dislocated hips because the relationship of the muscles to one another may differ from normal.

The key step of this procedure is the correct performance of the capsulotomy. In contrast to the usual z-shaped incision of the surgical dislocation approach, the capsule was incised anteriorly in a T-shaped manner (Fig. 1). To preserve as much capsular tissue as possible for later wrapping around the femoral head, care must be taken to execute the capsulotomy as close as possible to the bone of the acetabular rim. This was facilitated by manual traction on the leg. For optimal exposure and inspection of head and acetabulum, the hip was flexed and externally rotated and the leg was placed in a sterile bag on the opposite side of the table; this allowed dislocation of the head out of the capsule and facilitated continuation of the capsulotomy from inside and outside along the superior, posterior, and anteroinferior acetabular rim, including the area of the acetabular notch. In hips with subluxation, further mobilization of the posterolateral capsular flap is possible with an extended retinacular soft tissue flap [22]. This flap is an extension of the surgical dislocation approach and was primarily designed for safe subcapital reorientation in slipped capital femoral epiphysis. Briefly,

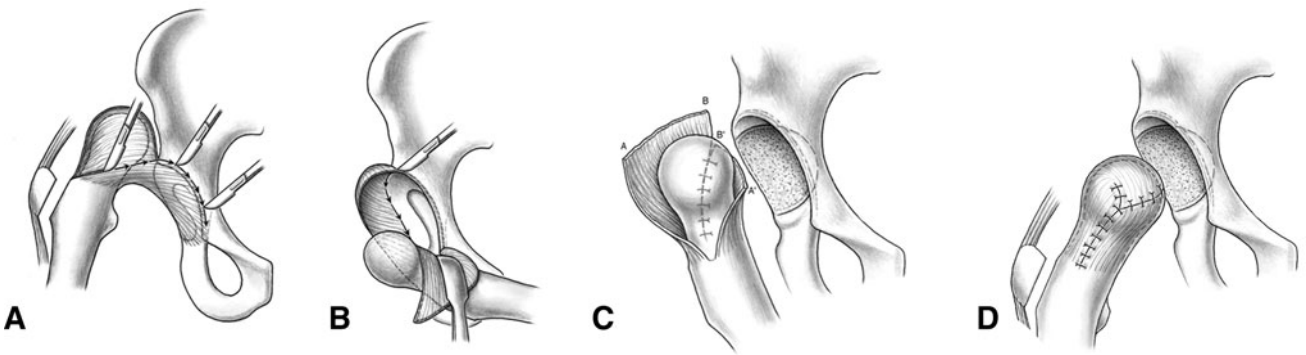

Fig. 1A–D Diagrams illustrate capsular incision. (**A**) The first incision of the capsule runs from the anterosuperior edge of the trochanteric osteotomy to the most superior point of the anterior rim. The incision is extended as close as possible to the anterior osseous rim down to the transverse ligament. With traction on the leg, the correct level of superior capsulotomy can be determined. (**B**) To inspect the joint, the elongated round ligament is excised. The femoral head is dislocated from the capsular cavity and held distally with the use of a Hohmann retractor hooked around the acetabular notch. Posterior capsulotomy can be executed from outside or inside. (**C**) After all capsular connections with the acetabular rim are sectioned, the leg is extended and the neck is lifted anteriorly using a bone hook. This allows approximation of the posterior capsular margins B to B′ and suture from caudad to cephalad. It is followed by the anterior suture A to A′. (**D**) Closure of the capsule over the head must be executed firmly but without tissue overlapping.

this flap extends from the capital attachment of the retinaculum down to the lesser trochanter and results from a strictly subperiosteal dissection of retinaculum and subperiosteal piecemeal trimming of the stable portion of the trochanter leveling to the posterior surface of the neck [22]. The flap contains the end branches of the medial femoral circumflex artery, responsible for the blood supply of the epiphysis [22]. The retinacular soft tissue flap is also used for relative lengthening of the neck [22], which decreases the problem of extraarticular impingement in some cases of capsular arthroplasty. It can occur after excavation of the primary socket when the neck is short and the base of the trochanter impinges against the posterior wall. In one of our patients, an additional varus intertrochanteric osteotomy was performed to establish the necessary clearance between femur and pelvis. To visualize and ream the true acetabulum, Hohmann retractors were positioned at the anterior and posterior rims and in the acetabular notch. Palpation of the rim thickness and clearing the fatty tissue from the fossa acetabuli ensured optimal orientation of the reamer. Hip arthroplasty reamers were used to open the socket, starting at 36-mm diameter. Reaming was first directed toward the notch and was interrupted repeatedly to assess the remaining thickness of the acetabular walls. We ceased reaming when cortical bone became visible centrally or at the walls. Next, we attempted a trial reduction without wrapping the head in the capsule. When trial reduction of the femoral head was not possible or only with a sciatic nerve becoming under tension already with the knee flexed, we stopped the attempt and performed a transverse subtrochanteric osteotomy at this stage to make the reduction easier. The ultimate amount of shortening, however, was determined at a later stage. Then, the femoral head, provisionally covered with the capsule, was reduced; if it had an easy and stable fit within the newly reamed acetabulum, any final femoral shortening or derotation osteotomies were performed, using a straight plate for fixation. We determined the need for shortening by the distance of the bone overlap at the femoral osteotomy when the head was reduced and the knee fully extended; the maximal amount of shortening was 3 cm. Derotation was executed after femoral shortening was completed and the fixation plate was temporarily applied with forceps; the amount of derotation was estimated between a plane perpendicular to the leg with 90° knee flexion and a Kirschner wire placed on the anterior surface of the neck. We aimed for a femoral anteversion of 15° to 20°. Only thereafter was the capsule sutured in place and covered the femoral head over its entire circumference (Fig. 1).

If the femoral head with the capsular covering was too large for the excavated acetabulum, we reduced the size of the femoral head [22]. First, the posterolateral portion of the retinacular flap was dissected as described above, while the posteromedial periosteum including Weitbrecht's ligament remained attached to the neck. The constant branch of the medial femoral circumflex artery running on the surface of Weitbrecht's ligament provides the blood supply to the medial epiphysis, while the retinacular vessels give blood to the lateral part of the head [28]. This supply configuration allows resection of a central segment of the head, which can be executed with parallel or triangular cuts. While the remaining medial portion of the head stays connected with the neck, the lateral portion together with a small extension of the neck is mobilized, reduced against the medial portion, and fixed with two to three screws. Femoral head reduction was performed in three of our nine hips in which further reaming of the socket would have created wall deficiencies. In six patients, five with low dislocations and a secondary acetabulum and one with high subluxation, we bone grafted the residual acetabular roof defect. The graft consisted of the fragment remaining after a relative neck lengthening or shortening osteotomy. The acetabular roof graft was fixed with screws. In five hips, intraoperative testing of ROM revealed extraarticular impingement; all had a short neck, a bulky greater trochanter, or both. Relative lengthening of the neck is basically the result of the piecemeal resection of the stable portion of the greater trochanter as described above [22]; it allows increased impingement-free hip motion. The greater trochanter was then advanced and fixed with two cortical screws; advancement was made easier with tenotomy of the long tendon of the gluteus minimus muscle along the anterior border of the mobile trochanteric fragment. Before refixation of the trochanter, the tightness of the capsular suture was tested with carefully executed motion to determine how much passive motion could be allowed during the initial postoperative period.

Postoperatively, the leg was held in a plaster spica cast with slight abduction. The plaster was bivalved after a few days for passive hip flexion to the amount of the intraoperative testing. We presumed, after 2 weeks, the capsule was sufficiently adherent to the cancellous bone to add rotatory movements. Nevertheless, the plaster was kept during the night for another 2 weeks for optimal protection of neutral abduction/adduction. Patients were toe-touch weightbearing once the plaster spica cast was removed during the day after Postoperative Week 2. When passive hip flexion was close to 90°, sitting on a chair/wheelchair was allowed. The patients remained toe-touch weightbearing for 8 weeks after surgery; with femoral head osteotomies, this period was 10 weeks. Consolidation of the osteotomies was judged by the following criteria: blurring of osteotomy lines, bridging callus on the extraarticular osteotomies, and filing of gaps with bone when compared with the postoperative radiographs or former controls. Once radiographs showed signs of consolidation

of all osteotomies (typically 8 to 10 weeks), weightbearing was gradually increased and active joint ROM exercises were advised. Full weightbearing was normally allowed at 10 to 12 weeks after surgery, the subtrochanteric osteotomy being normally the slowest to show sufficient consolidation. Muscle strengthening concentrated on the gluteus medius and started at 6 weeks with active contraction of this muscle in lateral decubitus, with the foot being placed on a bolster, high enough to avoid adduction of the leg. At 8 weeks, the patient was advised to start with elevation of the leg, which had to be kept extended at the hip and knee while accurate lateral position of the body had to be controlled. The next phase was to increase the time holding the leg elevated (maximum, 10 seconds), the number of exercises (maximum, 50/day), and the weight of the leg by putting sandbags on the ankle area (maximum, 5 kg). The time to reach the maximum of all three variables differed substantially from patient to patient. Most rapid recovery of muscle force was to be expected in hips that were preoperatively subluxated and had no muscle damage or scarring from previous surgery. Patient enthusiasm to seriously engage in and perform the exercises on a regular basis decreased with time; the best way to keep the motivation high was repeated monitoring. Finally, femoral implants may interfere and implant removal may allow more efficient training activity.

Patients and Methods

We retrospectively reviewed nine patients (one male, eight female) who underwent surgical hip dislocation with the modified Colonna procedure (Table 1). Eight of the nine patients underwent one or more additional procedures during the same anesthesia, including relative femoral neck lengthening (n = 5), femoral head reduction osteotomy (n = 3) [22], and intertrochanteric or subtrochanteric osteotomy (n = 7). Patient ages at the time of surgery ranged from 12 to 25 years. No patient had hip morphology amenable to open reduction, acetabular augmentation, or acetabular reorientation, although five patients had undergone a previous attempt using one or more of the above procedures. The minimum followup was 1 year (median, 2 years; mean, 7.5 years; range, 1–27 years). Five patients had followup from 1 to 2 years and four 5 to 27 years. No patients were lost to followup. No patients were recalled specifically for this study; all data were obtained from medical records and radiographs.

We obtained HHS for three of the five patients with short-term followup (Table 1). Patients were seen again at 4 weeks for a first clinical and radiographic check, or we obtained the necessary information from the family doctor. Further followup was advised for 8 weeks, 12 weeks, 1 year, and as needed thereafter. At each visit, we obtained an interval history, ROM of both hips, and abductor strength, as well as AP radiographs of the pelvis and a lateral or false-profile view of the operated hip.

Two of us (RG, ML, both treating surgeons) evaluated the radiographs of eight patients at latest followup. We determined the lateral center-edge angle and the roof angle, the distance between the medial border of the head and the ilioischial line, the level of the inferior border of the head relative to the teardrop line, and the joint space widths. Finally, we evaluated whether the epiphysis had a normal bony structure or showed signs of necrosis (Table 2).

Results

At latest followup, the mean HHS was 84 (n = 7) (range, 78–94) (Table 1). One patient underwent THA 27 years after surgery for increasing pain due to osteoarthritis during the previous 6 months. On the most recent followup radiographs, all patients with a preserved hip had a well-centered, vital femoral head with a large and congruent joint space. The two patients with spina bifida had pain during the dislocation events and had lost the capability to walk with their assistive devices. After surgery, both had regained their autonomy and, even more importantly, had substantially reduced the consumption of muscle relaxants.

Lateral center-edge angle and acetabular roof angle were within the optimal range, and together with a tendency of the distance head-ilioischial line to be slightly smaller than normal, the hips tended toward coxa profunda. With a broken Ménard-Shenton line in all patients, the placement of the center of rotation was slightly higher than normal. All hips had a normal bony structure of the femoral head and no flattening of the contour could be seen during the observation time.

One patient had a deep venous thrombosis of the lower leg (Patient 1) that resulted in no long-term consequences. In the patient with spina bifida who underwent additional femoral head reduction osteotomy (Patient 8), we identified a fracture of the intact medial part of the femoral neck with slight varus deformation at 4 weeks postoperatively. Immediate screw fixation was performed. The patient had uneventful further consolidation without signs of osteonecrosis at 1-year followup.

We describe two patients to illustrate the approach. Patient 2 was a female patient who presented at the age of 13 years with an untreated dislocation of the left femoral head that articulated with a secondary socket just proximal to the primary acetabulum (Fig. 2A). She had begun having left hip and low back pain with a substantial limp due to shortening and abductor weakness. The HHS at this time was 43. A capsular arthroplasty was performed using the

Table 1. Demographics and results

Patient	Sex	Morphology	Comorbidity	Previous surgeries	Age at surgery (years)	HHS before surgery (points)	Approach	Additional surgeries	Complication	Followup (years)	HHS at followup (points)	Secondary surgery	Other
1	Male	Low dislocation Secondary acetabulum		5 operations (femoral + acetabular)	23	43 (estimated)	SP	Femoral shortening + derotation	DVT	26	78	THA at 27-year followup	
2	Female	Low dislocation Secondary acetabulum			13	43 (estimated)	SHD	Femoral shortening + derotation Acetabular shelf		17	94	Metal extraction	
3	Female	High dislocation			13	33	SHD	Femoral shortening + derotation		12	90	Metal extraction	
4	Female	Low dislocation Secondary acetabulum	Arthrogryposis	Open reduction	21	33	SHD	Head reduction osteotomy Neck lengthening Femoral shortening + derotation Acetabular shelf		5	78		Vital head at 4-year followup
5	Female	Low dislocation Secondary acetabulum		3 operations (femoral + acetabular)	12	39	SHD	Neck lengthening Femoral shortening + derotation Acetabular shelf		2	82		
6	Female	High subluxation			21	57	SHD	Head reduction osteotomy Acetabular shelf		2	83		Pregnant Vital head at 1-year followup
7	Female	High subluxation Acetabular cartilage destruction		Femoral derotation Intraarticular Chiari	15	33	SHD	Neck lengthening		2	83		
8	Female	High subluxation Flat acetabulum	Spina bifida	2 operations (femoral + acetabular)	12	Not applicable (lost ambulatory status)	SHD	Head reduction osteotomy Neck lengthening Femoral shortening + derotation Acetabular shelf	Fracture-Stable, neck	1	Good ROM Ambulatory again with device	Screw fixation of neck fracture; uneventful healing	Vital head at 1-year followup
9	Female	Low dislocation Nearthrosis	Spina bifida		25	Not applicable (lost ambulatory status)	SHD	Neck lengthening Femoral varus + shortening Acetabular shelf		1	Good ROM Ambulatory again with device		

HHS = Harris hip score; SP = Smith-Petersen; SHD = surgical hip dislocation; DVT = deep venous thrombosis.

surgical dislocation approach; however, the gluteus medius was detached without osteotomy of the greater trochanter (Fig. 2B). The incision was extended distally for a subtrochanteric shortening and derotation osteotomy. A small lateral defect of the newly created roof was filled with bone from the femoral shortening. Seventeen years after surgery, she considers her left hip normal and enjoys several athletic activities, including jogging three times weekly (Fig. 2C). At latest followup, the patient noticed no difference in ROM or leg lengths, although on examination, there was a residual leg length difference of 2 cm. Her most recent HHS was 94, with minimal reduction of hip rotation.

Patient 4 was a female patient with arthrogryposis (Fig. 3). Since adolescence, she had refused to appear in public due to marked limping from a dislocated left hip with a radiographic appearance (Fig. 3A) similar to Patient 2. There was a slight coxa magna as a result of an attempt to reduce the hip in early childhood. She required NSAID pain medication regularly and her preoperative HHS was 33. Capsular arthroplasty was performed at an age of 21 years (Fig. 3B). With surgical dislocation of the hip, it became apparent relative lengthening of the neck was necessary to increase the clearance between femur and pelvis. Reaming of the primary acetabulum was limited by the acetabular morphology and would not accommodate the unreduced femoral head and capsule. Femoral head reduction osteotomy was then performed, using the technique mentioned earlier and described elsewhere in detail [22]. In addition, augmentation of the acetabular roof was necessary with an autologous graft from the relative neck lengthening. Finally, subtrochanteric shortening and derotation osteotomy were also performed. At 5-year followup, ROM was reduced due to the arthrogryposis but similar to that on the opposite side. At latest followup, the abductor force had improved to 5/5 and her gait was nearly normal. The patient regained a normal social life and no longer required pain medication. Her last HHS was 78. Radiography 4 years after surgery (Fig. 3C) showed a well-centered, vital femoral head within the new acetabulum. The joint space was large with reasonable congruency.

Table 2. Postoperative radiographic parameters for eight patients

Parameter	Mean or number of patients	Median	SD	Maximum	Minimum	ICC(2,1)*	Lower limit	Upper limit
Lateral center-edge angle (°)	36	36	6	47	29	0.919	0.663	0.983
Acetabular index	6	4	8	20	−1	0.842	0.443	0.965
Joint space width (mm)	5	5	1	6	2	0.936	0.713	0.987
Head/ilioischial line	4/8 touching							
	4/8 lateral							
Ménard-Shenton line	8/8 broken							
Joint space	3/8 congruent							
	4/8 medially narrowed							
	1/8 laterally narrowed							
Epiphysis bone structure	8/8 normal, no flattening							

* ICC = intraclass correlation coefficient, two-way random-effects model (absolute agreement).

Fig. 2A–C Images illustrate the case of Patient 2, a female patient who at 13 years old had low congenital dislocation of the left hip; she suffered from a substantial limp and moderate pain. (**A**) Pre- and (**B**) postoperative radiographs show the hips before and after the patient underwent capsular arthroplasty with a subtrochanteric shortening and derotational osteotomy and autologous bone augmentation of a small defect of the acetabular roof. (**C**) A long-term followup radiograph at 17 years postoperatively shows the head is well centered and the joint space is large and congruent. Clinically, the hip is nearly normal.

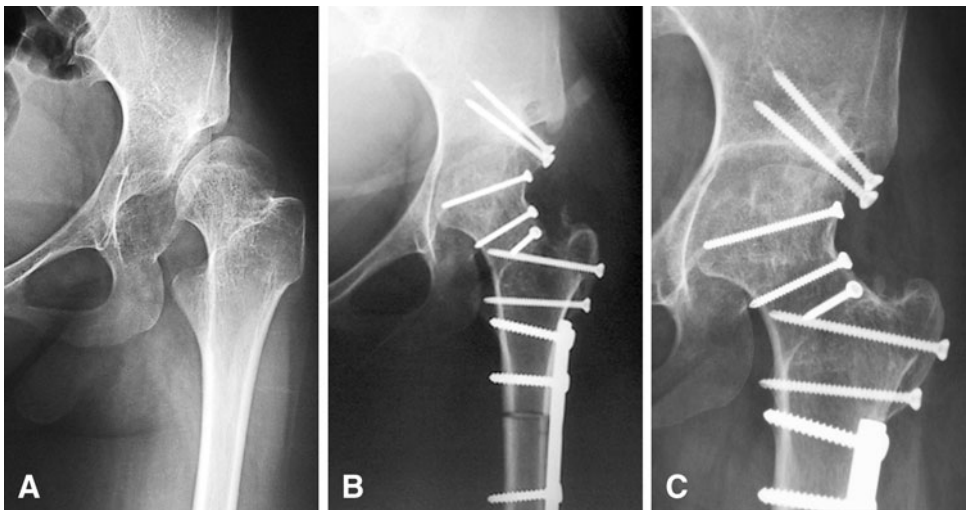

Fig. 3A–C Images illustrate the case of Patient 4, a 21-year-old woman with arthrogryposis and a left hip dislocation. The patient previously had one attempt at reduction in early childhood. On presentation, there was a severe limp and constant pain. (**A**) Pre- and (**B**) postoperative radiographs show the hip before and after the patient underwent capsular arthroplasty, relative femoral neck lengthening, femoral head reduction osteotomy, bone grafting of the acetabular roof, and subtrochanteric shortening and derotational osteotomy. (**C**) A most recent followup radiograph taken 4 years postoperatively shows the femoral head is vital and the joint space is large and well maintained. The functional performance is represented by an HHS of 78 and limitations of ROM are due mainly to the patient's underlying arthrogryposis.

Discussion

Capsular arthroplasty is a method of joint reconstruction for the dislocated hip. The capsule heals into the cancellous bone of the newly reamed acetabulum and turns into fibrocartilage [35]. Results have been inconsistent, with reports of hips that functioned surprisingly well for decades [8, 16, 38, 45, 48] and reports of frequent failures [4, 30, 33, 41], mainly due to femoral head necrosis (up to 50%) [8, 33, 45], joint stiffness (up to 30%) [23, 38], and deficient coverage and redislocation (up to 15%) [8, 23, 45]. The latter tempered enthusiasm for the procedure. However, the bigger factor decreasing the experience with this rather demanding procedure was that the frequency of dislocated hips decreased with modern screening techniques for DDH, especially ultrasound [24, 29, 39], allowing the initiation of early treatment options [47]. Simultaneously, the indications and success rates of THA improved such that joint arthroplasty is now increasingly used for younger patients. Nevertheless, published results for total joint arthroplasty in the 15- to 25-year age group are rare [26]. Arthroplasty registers tend to subsume all patients younger than 50 years into one group, but even doing so, the survival curve shows a clear drop after 10 years compared with the age group older than 60 years [46]. Reports about patients 20 years of age at surgery are far from promising, with 25% acetabular loosening after 6 years [31] and 30% revision, as well as a high prevalence of eccentric wear after 13 years [3]. In this debate, it seemed natural to reconsider the procedure of capsular arthroplasty with the purpose of reducing the number of complications, especially femoral head necrosis, by the application of more recent perceptions of the vascular supply of the hip [28] for safe surgical dislocation [21] and new intraarticular osteotomies [22]. We therefore described such a modified capsular arthroplasty and reported the functional and radiographic parameters and complications in nine hips undergoing this procedure.

Our study is subject to a number of limitations. First, the conditions for which surgery was performed varied, and over two decades, only nine capsular arthroplasties have been performed. Encouraged by the durability of the procedure in our first four patients, we have performed five of our capsular arthroplasties within the last 2 years. Meanwhile, two more patients have been operated on, and surgery has been scheduled for an additional five patients. However, limited observations confirm the potential of our modified capsular arthroplasty to reduce the major complications of the procedure as classically described. Second, the spectrum of indications for capsular arthroplasty is not yet firmly established. We have moved the age limits of the patients slightly toward the third decade, but ongoing verification is necessary; the same is true for indications other than DDH. Third, the execution of the capsular arthroplasty including the described additional techniques is demanding; in contrast to classic approaches, it requires detailed anatomic knowledge and surgical application, especially of the vascular anatomy of the hip. This needs special attention, although it has been shown the techniques can be performed by others with low complication rates [43]. Nonetheless, we believe this is a procedure that should be limited to the hands of experts

working in centers with a focus on joint-preserving hip surgery. Efforts have recently been made to further enhance knowledge and expertise by conferencing and publishing in multicenter study groups [43]. Fourth, followup is still not long enough to prove whether the additional procedures, such as shelf augmentation, relative lengthening of the neck, and femoral head reduction, are relevant for the longevity of the reconstruction, although so far no necrosis, stiffness, or insufficient coverage or redislocation have been observed.

Our technique differs from the classic procedure and early modifications such that eight of nine hips had several additional surgical steps at the time of the capsular arthroplasty. Seven of nine had femoral shortening with individual derotation, which is similar to the recommended modification of Stans and Coleman [45] and may have contributed per se to the absence of femoral head necrosis. Simultaneous shelf augmentation as performed in six of our patients to optimize femoral head coverage has not been reported in the literature; however, it was performed at a later stage in up to 11% of the hips [8]. Femoral head reduction as performed in three of our hips also increased containment; it was indicated when the AP diameter of the head did not allow reduction of the head-capsule complex into the socket, already reamed to the extremes. There is no such attempt described in the literature. The same is true for relative lengthening of the femoral neck, an additional procedure performed in six patients to increase the clearance for motion of the hip when intraoperative testing of ROM revealed osseous impingement between trochanteric bone and the acetabulum or ischium.

The HHSs of our seven nonneurogenic dislocations were close to or more than 80 at followup, and this level remained unchanged up to 12 to 26 years in the three hips with long observation time. All of our patients, especially those who had previous surgery, required considerable rehabilitation for abductor weakness. Our experience is similar to that in the literature [48]. Only Trevor [48] discussed postoperative rehabilitation in more detail. However, he mostly focused on the period of nonweightbearing of 3 months or 6 months (his preference). He advocated regular physiotherapy with particular attention to ROM and contractures. The Trendelenburg sign was negative in all but one of his patients without previous surgery and in only ½ of his patients with previous surgery. Only one of our patients regained full 5/5 abductor strength, six attained 4.5/5 abductor strength, and the two patients with spina bifida were limited by their neuromuscular status. Similar scores were reported in the literature after 20 years, especially when the position of the acetabulum was within anatomic ranges, coverage of the head was normal, and no signs of necrosis were detectable [8, 38].

Radiographically, the femoral head position in our patients tended to be slightly higher than normal when referenced to the teardrop; this is also mentioned in the literature [8, 38] and is a consequence of the excavation for the largest possible diameter of the socket. The head was tangent to or slightly lateral to the ilioischial line; with a lateral center-edge angle of 30° or more, both parameters indicate sufficient coverage. Together with a large joint space width and a normal bony structure of the epiphysis, the radiographic findings give reason to expect a favorable performance, as discussed in the literature for a group of hips with similar characteristics [8, 38].

We had one local complication related to femoral head reduction osteotomy: immediate screw fixation of the fractured medial head-neck column led to consolidation without further consequences. In contrast to the literature with rates from 0% to 50% [8, 33, 45], we had no patients with avascular necrosis. None of our patients had severe limitation of motion, while the literature suggests 8% to 30% have substantial restriction of motion [8, 23, 38]. Secondary interventions were only necessary in the above-mentioned case, compared to 18% and 28% as reported in the literature [8, 38].

In summary, total joint arthroplasty may be more familiar and function initially superiorly when performed for dislocated hips; however, as most young patients with THA ultimately require one or more revisions during their lifetime, there is a clear advantage to postponing THA by performing first a capsular arthroplasty. After capsular arthroplasty has led to a reconstruction of the bony acetabulum, subsequent THA is a technically easier and safer procedure with a higher survival potential than a primary prosthesis in a dislocated hip [6, 7, 18, 27]. In addition, patients undergoing revision of a previously successful capsular arthroplasty are considerably older when they have their joints replaced. Our approach introduces technical modifications to make this procedure more reliable and versatile. Nevertheless, we emphasize again this surgery is infrequent, requires special expertise, and will achieve the best results in the hands of surgeons with considerable experience.

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