Relative Neck Lengthening and Intracapital Osteotomy for Severe Perthes and Perthes-like Deformities

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Abstract
Intra-articular and extra-articular femoral Perthes deformities, or either, can result in severe alterations of the proximal femur and secondarily even involve the acetabulum, which can lead to premature osteoarthritis (OA) of the hip. In affected hips, joint damage due to impingement and instability may coexist. Classically, extra-articular impingement and associated abductor insufficiency in Perthes disease or similar pathologies are treated by trochanteric advancement. However, this leaves intra-articular impingement and instability unaddressed. The technique of surgical dislocation of the hip, in combination with a retinacular flap, allows for the relative lengthening of the femoral neck and even femoral head reduction osteotomy in such cases. This can be combined with an acetabular procedure to treat the secondary dysplasia. Since 2001, 14 patients with a minimum follow-up of 3 years have been treated by this technique without complications, such as femoral head osteonecrosis or trochanteric failures. All patients had markedly improved pain levels, hip mobility, and gait.

Osteotomies of the proximal femur to address biomechanical deformities are traditionally performed at the intertrochanteric and subtrochanteric levels and therefore are extracapsular. Even with transtrochanteric rotational osteotomies, at an extra-intracapsular level, the distance to the joint can be large, leading to secondary deformities, such as leg shortening and varus or valgus of the knee, which are undesirable in most instances. The extent of these associated deformities depends largely on the degree of the primary correction and on the distance to the joint level. Except for leg shortening, such adverse side corrections can be minimized by modifications of the technique and optimal implant selection; however, they could be more efficiently eliminated by performing the correction directly at the level of the deformity.

A better comprehension of the vascular supply to the femoral head has allowed the establishment of the technique for safe surgical dislocation of the hip. Routine surgical dislocation has led to a better appreciation of the pathophysiology of hip and prompted intra-operative, dynamic studies on hip vascularization, which, in turn, have led to a more detailed understanding of the perfusion process. Based on this detailed knowledge, safe approaches to the circumference of the neck of the femur have been developed, and new techniques, such as true femoral neck osteotomy, and even femoral head osteotomy, have become realistic options.

After a description of the technical considerations for surgical dislocation of the hip, this report will detail how to develop an extended retinacular flap. This retinacular flap provides safe access to the osseous femoral neck, in order to perform a relative lengthening of the femoral neck, and carries the vasculature supplying the femoral head to allow for a femoral head reduction osteotomy.

Materials and Methods
Surgical Hip Dislocation
In the past, dislocation of the femoral head out of the acetabular socket was executed rather infrequently, and publications did not refer to it without mentioning the risk of developing avascular necrosis of the femoral head. Following vascular injection studies that revealed the possibility of a safe hip dislocation, a surgical technique was developed and has
become a routine technique at many centers.\textsuperscript{14-21} The patient’s hip is positioned and draped in the lateral decubitus position, with the free leg placed on a bag, tunneled for the opposite leg. A 20 to 25 centimeter skin incision is made longitudinally over the anterior third of the palpated greater trochanter. The proximal fascia lata is incised anterior to the gluteus maximus muscle, the border of which is marked by one to several perforating vessels. The posterosuperior border of the greater trochanter becomes visible, at least palpable, with internal rotation of the extended hip and careful dissection of the gliding tissue over the trochanter. This is more difficult in patients with slipped capital femoral epiphysis or Perthes disease, where the tip of the trochanter may even stay in contact with the posterior acetabular wall and internal rotation may be difficult. The trochanteric osteotomy is performed using an oscillating saw; the osteotomy line is oriented in such a way that, proximally, 2 to 3 millimeters of the posterior portion of the gluteus medius muscle remain attached to the stable portion of the trochanter. With this technique, the majority of the piriformis tendon will remain on the stable trochanter. Further dissection of the capsule is performed proximal to the piriformis tendon, which helps to protect the zone of penetration of the ramus profundus into the capsule that is distal to the piriformis tendon. Furthermore, the constant branches of the inferior gluteal artery, running distal to the piriformis tendon along the external rotators, which eventually anastomose with the deep branch of the medial circumflex artery, are protected.\textsuperscript{5,10} Distally, the entire origin of the vastus lateralis muscle remains on the mobile trochanter. The maximum thickness of the trochanteric fragment should not exceed 1.5 centimeters. The dissection of the hip capsule between the piriformis tendon and the gluteus minimus muscle is facilitated by slight flexion, external rotation, and abduction in the hip. Further flexion and the use of Langenbeck retractors for the anterior soft-tissue flap allow the exposure of the anterior capsule. An important aspect of this step is the mobilization of the long tendon of the gluteus minimus muscle, which inserts into the anterior border of the mobile trochanter. As such, the trochanteric osteotomy is not digastric, as first described by Mercati and colleagues\textsuperscript{22} but is trigastric. The next step is a Z-shaped capsulotomy (right side). After assessing for mechanic conflicts during hip motion, the hip can be safely subluxed. Using curved scissors, the round ligament is cut; a bone hook pulling on the calcar widens the articular gap. This leads to complete dislocation, while the externally rotated leg is placed in an aseptic bag on the opposite side of the operating table. The leg position and rotation can be adjusted to allow visualization of the entire acetabulum and the majority of the femoral head. Morphologic abnormalities along with labral and articular cartilage injuries are now evaluated and registered in a drawing or photographically documented. When indicated, trimming of the acetabular rim is performed. The labrum is preserved and a labral refixation technique is utilized whenever possible.\textsuperscript{23,17} The planned surgical steps on the intracapsular femur are postponed for a later stage, after the elaboration of the extended retinacular soft-tissue flap has been dissected. As long as the femoral head cartilage is exposed to air, it should be constantly moistened.

Extended Retinacular Soft-Tissue Flap
To develop the flap, which is extended by subperiosteal release of the external rotators, the femoral head is initially reduced into the acetabular socket by bringing the leg back from the bag onto the table in full extension and mild internal rotation. The cancellous surface of the stable trochanter is exposed using two Langenbeck retractors. With a straight 1.5-centimeter osteotome, the posterior portion of the stable trochanter is reduced carefully, piece by piece. While performing this, the osteotome should not penetrate posteriorly out of the bone but should be used to weaken the fragment such that it can be manually bent and broken. The mobilized fragment is carefully turned outwards, so that a strictly subperiosteal dissection of the fragment can be completed under direct vision and with a knife. This process is repeated until the osteotomy surface levels the posterior and superior surface of the neck. Repeated palpations help to avoid cuts into the neck. At the superior circumference of the femoral neck, the periosteum anterior to the retinaculum is incised longitudinally with a knife. The retinacular border of the periosteum is carefully mobilized posteriorly, facilitated by careful trimming of the bony axilla at this level. The periosteum distal to the quadratus femoris muscle is also incised and mobilized posteriorly and distally. The subperiosteal flap continues to be developed in this manner until the posterior surface of the base of the lesser trochanter becomes visible. For a femoral head osteotomy, the flap is further separated from the osseous neck with the careful posteromedial dissection, using a small but sharp periosteal elevator. Care must be taken proximally to avoid damage to the area where the retinacular vessels enter into the epiphyseal bone. At this point, the posterior flap contains the deep branch of the medial femoral circumflex artery (MFCA), the anastomoses with the inferior gluteal artery, and the retinacular vessels. Dissection of the anterior and medial femoral neck as advocated for subcapital reorientation\textsuperscript{24} is not necessary for intracapital osteotomy. For most morphologies, the result of the dissection of the retinacular flap is equivalent with relative lengthening, described below.

At the end of the procedure, the borders of the periosteal flap are re-approximated loosely and any tension should be avoided. The same attitude is observed when closing the capsule. When the tension of the piriformis tendon on
the posterosuperior capsule is somewhat high, the tendon can be released from the capsule, but care must be taken to protect the deep branch of the MFCA perforating the capsule at this level.

Relative Lengthening of the Femoral Neck

The morphological appearance of hips that have sustained an insult during growth is frequently characterized by a deformed epiphysis, a short femoral neck, and a greater trochanter with a tip that is higher than the center of the femoral head. The majority of patients with such morphologies have had a history of Perthes disease or a disturbance of the epiphyseal perfusion during conservative treatment of hip dysplasia, with early closure of the head physis and undisturbed growth of the trochanteric physis. Other etiologies, such as trauma or as sequelae of an osteotomy, are also possible. The clinical problem in the majority of such hips may be characterized by weakness of the gluteus medius muscle, but with a closer look, there is also substantial pain and limitation of motion from impingement. Impingement can be extra-articular between the greater trochanter and the pelvis. In addition, more severe intra-articular impingement can be associated, due to an anterior flattening of the femoral head and a prominent anterolateral bony ridge of the short femoral neck. In the past, extra-articular advancement of the greater trochanter has been used frequently to treat this problem; it addresses the muscle weakness and part of the extra-articular impingement. The intra-articular component of impingement is not addressed by this procedure, and it is this component that is clinically more important in the long-run.

The procedure described here combines two goals: 1. the improvement of the muscular biomechanics, and 2. the resolution of the extra- and intra-articular impingement problem to allow for joint motion gain. The operation is deemed a “relative lengthening,” because only the superior circumference of the neck becomes longer by the trimming away of most of the trochanteric portion in its posterosuperior circumference, such that it becomes continuous with the smaller contour of the neck. Leg length remains the same, but muscle biomechanics and clearance for hip motion is improved.

As previously mentioned, the procedure is combined with the treatment of the individual intra-articular impingement. At the end of the procedure, the desired distal advancement of the trochanteric fragment is greatly facilitated by a release of the long tendinous head of the gluteus minimus muscle, which runs along the anterior border of the mobile trochanteric fragment. The definitive cephalad-caudad position of the trochanteric fragment, and therefore the amount of the trochanteric advancement, is determined using a bone hook to adjust the distal advancement and with palpatory assessment.

**Figure 1 A.** Schematic drawing showing a femoral head reduction osteotomy. The segment to be resected is depicted as a hatched line. The mobile fragment is pedicled on the retinaculum. The blood supply for the stable medial segment originates from the postero-medial branch of the medial femoral circumflex artery. B. After optimal placement of the lateral fragment, a gap towards the trochanteric area has to be filled with bone. Two or three 3.5-mm screws are necessary for fixation of the head fragment. A relative neck lengthening is performed for trochanteric advancement.
Figure 2 Perthes disease in a 12-year-old male. A, There is extrusion due to coxa magna, coxa plana, and subluxation. The central necrosis is flanked by a healthy medial and lateral epiphyseal pillar. B, Painful hinged abduction with the acetabular edge entrenching on the necrosis. C, Unexpected slight further subluxation 3 months after head reduction osteotomy, although intra-operatively the head appeared to be fully contained and stable. With regard to the clearly improved clinical situation, the reevaluated PAO was postponed. D, Radiographic result 2 years after the index surgery. The patient has re-developed some pain and limping, leading to the decision for an additional PAO. E, Nine months after PAO, the femoral head is sufficiently covered and hip function is again normalized. The clinically asymptomatic pseudarthrosis will be addressed by bone grating when the hardware is to be removed.
of the relative position of the trochanteric fragment. Two 3.5 or 4.5 millimeter screws are usually sufficient to stabilize the advanced trochanteric fragment.

**Femoral Head Reduction Osteotomy**

Based on a more advanced appreciation of hip vascularity mentioned earlier, a reduction of the size of the femoral head by resecting a middle segment became feasible without risking necrosis of the remaining two fragments (Fig. 1). The first step of such a procedure is the mobilization of the extended retinacular flap and the relative neck lengthening described above. With its retinacular blood supply, a lateral segment of the head can be of unlimited size and can be separated and mobilized. The medial segment of the head is perfused by the posteromedial branch of the MCFA similar to a Pipkin II fragment; however, it does not need to be separated from the metaphysis. It is preferred to extend the size of this segment not much over the level of the fovea capitis. The resected portion of the head can be a segment with parallel cuts, a triangular or a trapezoid formation, according to the given deformity of the femoral head; although the osteotomies should be oriented in a sagittal direction, there is a certain degree of spatial variability. The goal of the resection is that the contours of the remaining segments can be matched in congruity without a step of the two cartilage surfaces. The final head size should fit into the socket but should not be too small. Peripheral irregularities can be fine-tuned with a scalpel or osteotome. Leveling of the mobile lateral head and neck segment may create a gap with the metaphysis; this is filled with bone from the trochanteric trimming. Two 3.5 millimeter screws, inserted from the mobile into the stable head fragment, have been sufficient for fixation. The acetabular roof has more or less adapted to the deformed head, resulting in a deformation from lateral flattening of the edge to a severe acetabular dysplasia. The femoral head, although smaller after the osteotomy, may not find or keep a well-reduced and stable position in such a socket. In such instances, it is recommended to sufficiently increase the joint stability by adding a peri-acetabular osteotomy (PAO). This is best performed under the same anesthesia, after repositioning of the patient from lateral to supine decubitus. However, the first ischial cut can be easily performed prior to repositioning through the lateral incision, between the inferior gemellus and obturator externus muscles, with optimal visual control of the sciatic nerve.

**Results: Case Series**

Since 2001, 14 femoral head reduction osteotomies have been performed; 13 for Perthes or Perthes-like deformities. In one hip, a Colonna procedure could only be finished after the head was reduced in size to fit into the maximally excavated socket. Patients’ ages ranged between 9 and 21 years. Eight hips had a PAO, together with the reduction osteotomy, and three had the additional surgery at a later stage (Fig. 2). One earlier case had a femoral varus osteotomy 8 weeks later to stabilize the head in the socket. Overall, only one hip did not need additional correction on the acetabular side. All osteotomies healed within 6 to 8 weeks, and none developed osteonecrosis at a minimum follow-up of 3 years. All patients reported improved motion, without substantial pain.

**Discussion**

Osteotomies of the proximal femur for osteoarthritis (OA) of the hip joint have become less indicated with the increasing popularity of total hip arthroplasty (THA), even for younger patients. Femoral osteotomies aimed at improving coverage and congruency as well as vertical loading of the hip; however, the results are often unpredictable. With introduction of the impingement concept as an initiating factor of OA, the therapeutic perception changed from treating established OA toward treating deformities of the hip leading to impingement; if possible, this should be executed before degenerative changes of the joint cartilage are established.

Relative lengthening of the femoral neck has been mentioned in earlier publications. The technique evolved over time when intra-operative control of free motion, revealing frequent residual impingement between the stable trochanter and the posterior acetabular wall in abduction, external rotation, and with combinations, made removal of further trochanteric bone necessary. The morbidity of the relative lengthening procedure, including healing problems of the greater trochanter, is quite small. In fact, it is not higher than for surgical dislocation alone; this aspect may increase the biomechanical value of the procedure. The step from relative lengthening of the neck to the elaboration of the extended retinacular flap was small, but it opened the door to a new class of intracapsular surgery.

Femoral head reduction osteotomy has a rare but distinct indication in older children and adolescents. It is a direct approach to a morphology of the femoral head or the joint, or both, which does not have a true alternative option and, if left untreated, would deteriorate rapidly or the situation would be unacceptable due to the caused clinical limitations. Femoral head osteotomy is always combined with relative lengthening of the neck. However, it may be performed without an additional joint-stabilizing procedure if secondary deformation of the acetabulum is absent or only minimal. We underestimated the remaining subluxation tendency in four of our cases and had to compensate it at a later stage with a varus intertrochanteric osteotomy and a reorientation of the acetabulum, respectively. With the longest follow-up at 9 years, intracapsital osteotomy has promising radiographical and clinical results and seems to be advantageous over other salvage procedures covering the extruded portion of the deformed femoral head, such as shelf osteoplasty or Chiari osteotomy.
Disclosure Statement
None of the authors have a financial or proprietary interest in the subject matter or materials discussed, including, but not limited to, employment, consultancies, stock ownership, honoraria, and paid expert testimony.

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