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Correction of deformity associated with healed slipped capital femoral epiphysis by Imhäuser osteotomy

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Abstract

Slipped Capital Femoral Epiphysis is the leading cause of limp in the adolescent population. This study aimed to discuss that intertrochanteric Imhäuser osteotomy led to an improved functional outcome, and discussing indications, contraindications and surgical technique of Imhäuser osteotomy. In moderate and severe slips, residual growth and remodeling after in situ stabilization are unable to compensate for the remaining femoral neck deformity. In these slips, a modified Dunn procedure might be more effective in order to reduce the risk of early onset hip osteoarthritis but carries high risk for avascular necrosis.Subtrochentric Imhauser osteotomy provides excellent option for correction of the residual deformities in chronic or healed SCFE.The Imhauser osteotomy is Subtrochentric valgus, flexion and internal rotation so correct the deformities in the chronic cases of SCFE. In consideration of our 23-year follow-up and in regard to other studies, we still consider the Imhauser ¨user osteotomy to be indicated for SCFE with angles of displacement >40°.

Keyword: SCFE, Imhäuser osteotomy.

1. Introduction

Slipped Capital Femoral Epiphysis is the leading cause of limp in the adolescent population. Hip deformity of the typical SCFE consists of the primary deformity (slip), followed by the secondary deformities of the femoral neck. The primary deformation starts with external rotation and lateral (Varus) tilt of the femoral neck relative to the upper femoral epiphysis. Secondary deformities emerge at about three weeks after slip onset and exacerbate if there is any delay in diagnosis and treatment [1].

The prevalence of SCFE ranges from 0.71 to 10.8 per 100,000 children, but there is seasonal (increased incidence in summer and autumn in northern countries), geographical (only 1-2: 100,000 in Japan and Singapore) and racial (more frequent in Hispanic, African-American, Indian) variation. Boys are more frequent affected compared to girls (boys to girl's ratio 1.5: 1). [2].

The etiology of SCFE is multifactorial. .Factors that may predispose to SCFE are mechanical factors that increase the shear forces on the growth cartilage and lead to a rupture at the level of the hypertrophic cell zone, which is the weakest area of the growth cartilage. Various biochemical factors lead to inherent weakening of the growth cartilage. Estrogens accelerate physeal closure. This explains the rare occurrence of SCFE in girls, especially after menarche. [3].

Normal femoral neck growth is accomplished by endochondral ossification at the proximal femoral physis. This process seems to be disturbed in SCFE. Several changes of the affected proximal femoral physis are observed on microscopy. Histochemical and ultrastructural changes are observed. The chondrocytes in the proliferating and hypertrophic zones present increased nuclear and cytoplasmic density and contain a high amount of cytoplasmic glycogen. Collagen and proteoglycan disorders are found in the extracellular matrix. [4].

The clinical presentation of SCFE depends on the extent and on the rate of progression of the slip. A preslip stage precedes the actual slip. The child may complain of mild pain at the hip and/or the ipsilateral thigh and knee and presents a limp. Frank slippage of the femoral epiphysis on the metaphysis ensues along with exacerbation of hip associated symptoms: Pain, stiffness, restriction of flexion, adduction and internal rotation, increased external rotation and shortening of the affected lower limb. Mild slips do not cause significant gait alterations compared to healthy children of the same age and weight. However, moderate and severe slips lead to the development of compensatory movements during gait cycle in order to avoid the impingement of the deformed femoral neck on the acetabulum [5].

SCFE is classified according to the duration of the symptoms as acute (<3/52), chronic (>3/52) or acute on chronic (>3/52 with episodes of exacerbation).This classification is not helpful in predicting the risk for the most serious complication of SCFE, namely avascular necrosis (AVN) of the capital femoral epiphysis. On the contrary, a classification according to the ability of the patient to walk is more efficient to predict the risk of AVN. If the patient is ambulating ("walks in"), SCFE is deemed "stable". A dramatic, extremely painful clinical presentation with the patient completely unable to walk, even with support, is characteristic of an "unstable" SCFE. The slip angle is the difference of the head-shaft angle between the painful and the healthy contralateral hip. The head-shaft angle is measured on the FL projection and is deemed the angle formed between the axis of the diaphysis and the axis of the epiphysis (axis of the epiphysis: a line perpendicular to the line connecting both ends of the epiphysis). According to the slip angle, SCFE is classified as mild (slip angle <30), moderate (30-50) and severe (> 50). [6].

Imaging tests are mandatory in order to set the diagnosis, to describe the severity of the slip and to monitor short and long term outcomes after slip stabilization. Pelvis X-rays, Anteroposterior (AP) and Frog Lateral (FL) views are easily obtained and are sufficient to set the diagnosis in almost all cases the following signs are diagnostic of SCFE. The femoral neck line (Klein's line) does not intersect the capital femoral epiphysis. This sign is occasionally referred as "the Trethovan's sign". The Metaphyseal Blanch sign (Steel-Bloomberg sign): Increased density on plain x-ray caused by the overlapping of the retroverted capital femoral epiphysis on the anteverted femoral neck. The Capener's sign: Decreased overlapping of the femoral neck on the posterior acetabular wall. The acetabulotrochanteric distance (ATD) is the distance between a line that spans the superolateral edge of the acetabulum and a line parallel to the first line that passes through the top of each greater trochanter. Normally, the ATD is >20 mm. An ATD <5 mm is associated with a positive Trendelenburg's sign. The acetabulotrochanteric angle (ATA) is the angle formed between the line connecting the superolateral edge of the acetabulum and the line that connects the tip of the greater trochanter. An ATA >10 is indicative of SCFE. Imaging modalities, such as Bone scan, Computerized Axial Tomography (CAT) and Magnetic Resonance Imaging (MRI) are not first-line examinations, because the diagnosis and treatment of SCFE is largely based on plain radiographs. [7].

Whatever the clinical presentation, SCFE is a surgical emergency. Surgery for SCFE aims to stabilize the slip and to minimize post-slip sequellae, such as femoroacetabular impingement and secondary hip osteoarthritis. The treatment of stable SCFE The treatment of stable slips is dictated by the severity of the deformity, the child's remaining growth and the surgeon's preference and surgical experience. In situ stabilization is still the preferred treatment for stable slips. Compensatory subtrochanteric femoral osteotomies provide excellent options for correction of the residual deformities in patients with healed SCFE or following pinning in situ [7].

The following options are available for the treatment of unstable SCFE. Incidental (postural) closed reduction of the epiphysis on the metaphysis .after simple positioning of the patient on the surgical table, without any manipulation and any attempt to obtain anatomic reduction. Targeted closed reduction an attempt of closed reduction with manipulation of the hip under general anesthesia, with or without decompression of the hematoma, is followed by pin or screw fixation. Partial anatomical reduction of the capital femoral epiphysis (Parsch method) is achieved by limited anterior arthrotomy of the hip and reduction of the slip by direct pressure on the neck metaphysis. Reduction stops when the epiphysis reaches the posteroinferior neck callus. Fixation at this point follows. Anatomical reduction of the capital femoral epiphysis, open (Modified Dunn Procedure) or arthroscopic, is accomplished after posteroinferior neck callus removal. Since there are no prospective randomized trials to evaluate the efficacy of each method, the simplest and most accepted treatment is the emergent (within 8-24 hours) postural reduction of the slip after hematoma decompression, followed by in situ stabilization. [9].

Treatment of stable mild slips. IN situ stabilization is the universally accepted treatment for stable mild slips (slip angle <30), preferably by a technique that does not restrict the remaining growth of the proximal femoral epiphysis. Treatment of stable severe slips. In stable severe slips, many surgeons suggest that in situ stabilization should be combined either with a corrective (anatomic reduction of the slip, through the growth cartilage) osteotomy or with a femoral head reorientation (compensatory, non-anatomic) osteotomy (at the middle or the base of the femoral neck, intertrochanteric or sub trochanteric) [10].

2. Treatment of residual deformity in chronic and healed SCFE by Imhauser osteotomy

Corrective intertrochanteric osteotomy as proposed by Imhäuser in 1957 is to be understood as a "secondary prophylactic intervention" that aims at achieving the best possible restoration of anatomic relationships at the hip joint to relieve prearthritic deformity and, consequently, reduce the incidence of coxarthrosis. Although intertrochanteric osteotomy only achieves partial correction of the deformity, at least for moderate types of SCFE, it still appears advantageous when compared to the risk of femoral head necrosis associated with correction at the subcapital level. [11].

Advantages

- Adequate surgical corrective potential (depending on the initial status of the epiphysis) of 20–60° .
- Level of correction to correspond with the epiphyseal dislocation, additional adjustment by outer rotation/valgization .
- Minimal risk of femoral head necrosis.

Disadvantages

- Incomplete restoration of coxal femoral anatomy.
- Potential injury to the vessel and nerve structures.
- Implant removal is necessary.

Indications

- Chronic and subacute forms of SCFE.
- Epiphyseal displacement angle in the transverse plane, ET (epiphyseal retrotorsion angle) of 30–60°.
- Epiphyseal displacement angle in the frontal plane of more than 20°.

Contraindications

- Metaphyseal impingement.
- Manifest secondary coxarthrosis.
- Traumatic epiphyseolysis.

3. Patient and Parent Information

- General surgical risks (infection including osteomyelitis, thromboembolic complications, postoperative bleeding, potential nerve and vessel damage) .
- Disruption of the blood supply to the femoral head (femoral head necrosis) as a result of osteotomy close to the vessels, but relatively low risk of impaired

circulation to the femoral head due to the operation because transfemoral osteotomy is performed at the intertrochanteric level distal to the circumflex vessels.
- Transient femoroacetabular chondrolysis; pseudarthrosis of the intertrochanteric osteotomy .
- Possibility of implant-related complications (fatigue failure, correction loss, necessity of refixation of the epiphysis due to longitudinal growth, implant removal later on).
- Unloading of the extremity until radiologic confirmation of osseous consolidation of the osteotomy or fusions of the epiphyseal cartilage .
- Persistent relative leg length differences, functional limitations at the hip joint (mostly flexion/internal rotation), secondary risk of delayed coxarthrosis [12].

4. Preoperative Work Up
- Clinical examination of hip joint mobility (documentation of contractures, especially internal rotation in flexion and extensibility) .
- Radiographs of the proximal femur, anteroposterior in neutral rotation and axial according to Dunn-Rippstein (hip/knee in 90° flexion/hip in 20° abduction/neutral rotation) or according to Imhäuser (hip/knee in 90° flexion/hip in 45° abduction/ neutral rotation .
- Measurement of the epiphyseal displacement angle in the frontal (ED angle) and transverses planes (ET angle) on the radiographic image. Tabular calculation of the real values, if the projected angle values are high .
- Image-based diagnostic option: measurement of the epiphyseal displacement angle based on CT/MRI investigation of the pelvis.
- Preoperative planning sketches, planned osteotomy level, correction alignment (flexion/internal rotation) and extent, the selected implants are also sketched .
- Preoperative planning: a correct preoperative plan can really only be drawn up on the basis of mathematically calculated values for wedge size and orientation. To avoid this time-consuming and complicated geometric and mathematical planning procedure that would be necessary for each individual epiphyseal dislocation, a simple pattern can be followed: an epiphysis in posterocaudal displacement requires a wedge with anterior base and needs anterocranial relocation, i.e., by inflection osteotomy. Under certain circumstances, the position of the epiphysis can only be improved by additional outer rotation of the proximal femur, i.e., internal rotation of the distal fragment. Both corrective procedures, namely, inflection osteotomy and internal rotation of the distal fragment, naturally require reinforcement of the antetorsion of the femoral neck, that is, angulation of the proximal femur in an anterior direction. Since the capsule sheath at the hip joint is narrow, the extent of this corrective adjustment of the proximal femur, aimed at improving the position of the epiphysis, is not unlimited. Clinical and surgical experience teaches that an inflection osteotomy of about 30° (wedge with anterior base) is sufficient to elevate the epiphysis from its nonphysiological posterocaudal position and shift it anteriorly so that an almost normal articulation of the epiphysis in the acetabulum is achieved and anterior femoral neck impingement is avoided. Experience has shown that an inflection osteotomy > 35° cannot be realized at the hip joint without long-term flexional deformity. Supplementary outer rotation of the proximal fragment by 10–20° must also be seen in relation to correction of flexural movement and reinforcement of antetorsion of the proximal femur and is, therefore, only possible as a supplementary corrective procedure for the proximal fragment. A corrective wedge with anterolateral base will only occasionally be beneficial in special cases of epiphyseal malposition with a distinct Varus component.[13].

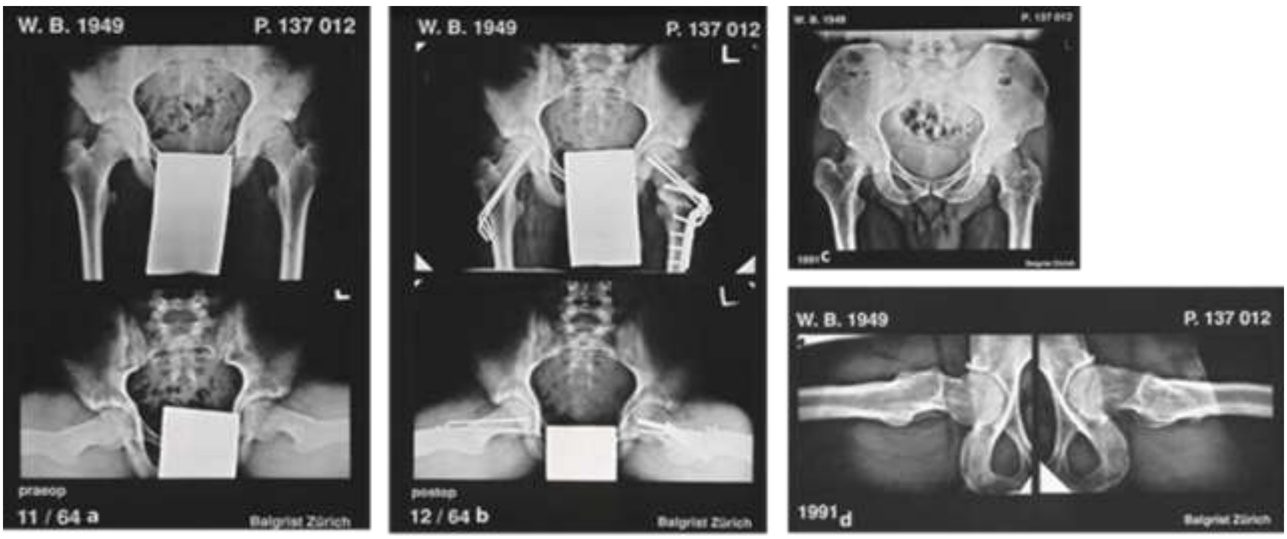

Fig. (1) X rays showing pre and post correction by Imhauser osteotomy [14].

Surgical technique

Active With the patient on a radiolucent tabletop or a fracture table, and C-arm fluoroscopy available, the entire affected extremity is draped free. The proximal femoral cortex is exposed through a lateral incision. The proper level of osteotomy is confirmed with fluoroscopy. A longitudinal mark should be made along the anterolateral margin of the proximal femur spanning the anticipated wedge of bone to be resected to serve as a rotation-orientation mark. Stabilization of the femoral epiphysis with two smooth 3.0-mm Kirschner/Steinmann nails, inserted slightly mediolaterally and running parallel from the anterolateral base of the femoral neck into the posterocaudally displaced epiphysis. This procedure is carried out under image intensification to monitor direction and depth of drilling in the frontal (a) and axial (b) views. The nail tips are then bent and shortened. The planned position of the plate blade must be taken into account when inserting the nails to avoid implant conflict later (insertion site for the plate blade proximal to the center of calcar femoris [15].

Insertion of marker Kirschner wires (trochanteric Kirschner wire for blade position, and rotation Kirschner wire) under image intensification. The osteotomy plane is identified immediately above the lesser trochanter perpendicular to the shaft. The base of the flexion wedge is taken to lie anteriorly with the leg in the neutral position. The Kirschner wire for blade position must be positioned high enough (sufficient bone distance of 2.0–2.5 cm between the blade insertion site and the intertrochanteric osteotomy). The trochanteric Kirschner wire is inserted perpendicular to the femoral shaft, i.e., the impaction angle of the seating chisel to the femoral shaft is 90° and 0° to a few degrees antetorsion, and the anterior opening angle is 30°. Strict attention must be paid to ensuring that the Kirschner wire, and later on the plate blade, rests in the middle of the greater trochanter and does not perforate the calcar femoris or the anterior or posterior borders of the femoral neck. If the bones are small, the adolescent angled blade plate should be chosen. Gradual impaction of the seating chisel by repeated blows back and forth to avoid jamming, guided by the slotted hammer, in proper relationship to the Kirschner wires, and with an anterior aperture to the femoral shaft axis of 30° in most cases. When blade depth has been reached, slight retraction of the seating chisel [15].

The intertrochanteric osteotomies are performed whereby the soft tissues are protected with Hohmann elevators. Initial osteotomy immediately proximal to the lesser trochanter perpendicular to the femoral axis, followed by excision of a bone wedge with anterior base of 30° from the proximal fragment in accordance with the actual deformity and preoperative planning. Anterior means that the leg is in the central neutral position (patella is directed anteriorly). The osteotomies are performed with the oscillating saw with constant water cooling to prevent excessive heat generation. Rotation of the bone fragments is assessed by means of the rotation Kirschner wires[15].

Withdrawal of the seating chisel, insertion or careful impaction of the plate blade. The distal fragment is realigned so that the osteotomy surfaces are in contact and can be temporarily stabilized with bone holding forceps (a). After evaluation of axial and rotatory alignment, the tensioning device is mounted to apply interfragmentary compression to the osteotomy (b). 4.5-mm cortex screws are inserted into two plate holes and anchored bicortically. All marker Kirschner wires are removed. Assessment of free hip joint mobility: in hip flexion, adequate internal and external rotation is required; in hip extension, there is restricted outer rotation due to the correction, possibly also slight flexural deformity. Postoperatively, attention must be paid to ensuring that the leg is in a neutral rotatory position [15].

After correction osteotomy, visible flexural position of the coxal end of the femur including the femoral head (a: anterior view, b: anterolateral view) in relation to the distal fragment, with corresponding recentering of the femoral epiphysis in relation to the acetabulum and increased, impingement-free flexion and internal rotation capabilities at the hip joint. Subsequent readaptation of the vastus lateralis muscles, closure of the fascia lata over a subfascial Redon drain, and wound closure in layers[15].

3. Complications

Soft-tissue infection and osteomyelitis: for superficial epifascial soft-tissue infection, systemic antibiotic medication and immobilization, possible local incision of the skin cover and superficial wound debridement; for subfascial deep infection with an osteomyelitic component, immediate extensive surgical debridement, including jet lavage and replacement of the metal implants, adjuvant long-term sensitivity-adjusted parenteral antibiotics. [16].

Pressure neuropathies of the sciatic nerve as a result of hook pressure or incorrect position of implants [16].

Pull-out of the plate blade: reosteosynthesis of the intertrochanteric osteotomy, if necessary, repositioning of the blade in the proximal fragment taking the need for a sufficient bone bridge (approximately 2.0 cm) opposite the intertrochanteric osteotomy into account [16].

Fatigue failure of the implants stabilizing the epiphysis, namely, after application of rigid cannulated screws, or difficulties with extraction of such, with corresponding damage to the bone.

Pseudarthrosis of the intertrochanteric osteotomy: surgical restabilization after removal of the fibrous interposition tissue, possibly with simultaneous moderate valgization and revision plate stabilization with an axial-compression angled blade DC plate.

Restricted motion at the hip joint due to capsuloligamentous contractures in the context of slipped capital femoral epiphysis, accentuated by inflection correction osteotomy, as a result of femoral chondrolysis as a possible concomitant symptom of epiphyseolysis: continuous active-assisted exercises supervised by a physiotherapist and simultaneous adequate analgesia, careful, purely active stretching of the contracted anterior joint capsule without forced passive pressure [16].

Leg length differences: combination of basic pathology (loss of length due to the posterocaudal displacement process) and blocked longitudinal growth of the epiphyseal plate (premature epiphyseal closure due to insertion of screws). If necessary, epiphyseodesis of the distal femur on the healthy side [16].

Femoral head necrosis in chronic forms of slipped capital femoral epiphysis without manipulative or surgical intervention is rare. Impaired circulation to the femoral head can be practically ignored for correction osteotomies at the intertrochanteric level performed in correct surgical technique [16].

4. Discussion

Imhäuser [17] first described his intertrochanteric osteotomy in 1956 in order to introduce flexion and internal rotation, with a degree of valgus to the proximal femur. In 1977, he published the results of his osteotomies with an 11 to 22 year follow-up of 55 patients.23 He recruited information via a questionnaire from 13 more patients who were unable to attend for clinical review, and of the total 68 patients, 66 were pain free and functional. Of the 55 patients who attended for clinical review, five had significant limitation of movement, and 27% of hips showed radiological degenerative change. More recent studies with better osteosynthesis techniques have shown similar acceptable rates of success using the Imhäuser osteotomy. Schai, Exner and Hänsch [18] reported results on 51 patients, with a mean follow-up of 24 years, showing excellent clinical outcome in 75% of hips, with moderate and severe osteoarthritis on radiographs in 28% and 17%, respectively, and an overall ON rate of 2%.24 Kartenbender, Cordier and Katthagen [19] with an average follow-up of 23.4 years reported excellent or good clinical outcomes in 77% of hips; degenerative changes on radiograph being mild in 38.4%, moderate in 25.6% and severe in 7.7%, with an ON rate of 5.1%. Fujak et al [20] also showed acceptable results in 28 patients followed-up for a mean of 24 years, with excellent clinical outcomes in 17 patients, and no patient developing arthritis as seen on radiographs compared with the contralateral hip in 24 patients. These studies did not use validated scoring systems and the high rates of patient satisfaction could be questioned, given the relatively high incidence of degenerative changes seen on the radiographs. There have been two reports of an intertrochanteric osteotomy with an open femoral neck osteoplasty and both have used a surgical femoral head dislocation via a trochanteric 'flip' osteotomy as described by Ganz et al. Spencer, Millis and Kim [21] reported the result of intertrochanteric osteotomy on 19 patients of whom 12 were due to a SCFE.27 Six of these patients had surgical dislocation with osteoplasty of the femoral neck. The remaining six had the same procedure combined with an intertrochanteric osteotomy. An intra-operative decision following the osteoplasty was made to see if there was still impingement in the functional ROM, after hip reduction. They did not report any patients with ON and four of the six patients in the isolated osteoplasty group, and five of the six patients in the osteoplasty and intertrochanteric osteotomy group, showed improvement in their post-operative outcome using the Western Ontario McMaster University Osteoarthritis Index (WOMAC)[22] . However, Spencer et al [23] did acknowledge that the mean follow-up was only 12 months, and the scoring system they used had been designed to assess the functional ability of elderly arthritic patients rather than younger more active patients. Bali et al. used the NAHS, which has been validated in assessing the functional outcome for younger patients.the study identified better NAHSs, suggesting an improved outcome in those patients who had an osteoplasty of the femoral neck. However, the mean 15.1 point higher scores in the osteoplasty group did not reach statistical significance. The two patients who developed osteoarthritis requiring joint replacement had not received an osteoplasty, and both developed degenerative changes in the anterosuperior acetabulum consistent with damage from a residual cam deformity. While it seems that those patients who did not have an osteoplasty had a poorer functional outcome, they recognise that their follow-up has been longer and so their hips have had more time to develop degenerative changes. The decision to perform osteoplasty in our series was largely based on the size of any cam lesion and those patients with smaller cam/metaphyseal deformities were not subjected to an osteoplasty. The majority of patients with SCFE of any grade will have an increased alpha angle, which is formed by a line through the center of the femoral head, along the axis of the femoral neck and a line connecting the center of the femoral head to a point where the femoral head extrudes a circle drawn around it.While an elevated angle suggests an increased risk of impingement from a cam lesion, it is not clear whether all patients undergoing an intertrochanteric osteotomy would benefit from osteoplasty. They would advocate an osteoplasty if there is a cam lesion that clearly limits flexion and internal rotation of the hip. In patients who develop SCFE in early adolescence, there is often sufficient remodeling of the cam and an osteotomy alone will suffice. In patients closer to skeletal maturity, there was often a large cam, the offset of which is significantly larger than the radius of the femoral head.

5. Conclusion

The Imhauser osteotomy is still a proven operation for correction of SCFE in severe cases, as shown by our long-term results. We suggest that correction by osteotomy should be reserved for gliding angles >40° because lesser angles of deformity will remodel. Crucial for good results is accurate planning and preparation of the operation as well as technically perfect realization of the complex operation. That is why the three-dimensional intertrochanteric operation should be performed only by specialized teams and clinics. In consideration of our 23-year follow-up and in regard to other studies, we still consider the Imhauser ¨user osteotomy to be indicated for SCFE with angles of displacement >40°.

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