Diagnosis and Management of Developmental Dysplasia of the Hip from Triradiate Closure Through Young Adulthood

Klaus A. Siebenrock, MD, Simon D. Steppacher, MD, Christoph E. Albers, MD, Pascal C. Haefeli, MD, and Moritz Tannast, MD

Management of the Acetabular Side
Closure of the triradiate cartilage may occur as early as eight to ten years of age. Thus, typically the pelvis of a very young teenager already is amenable to different kinds of juxta-acetabular osteotomies for the treatment of hip disorders. Treatment options for the dysplastic acetabulum can be divided into (1) augmentation and (2) reorientation procedures. Augmentation procedures include a Chiari osteotomy or different techniques of shelf procedures, based on the principle of load reduction by distributing load through a larger surface area. However, the potentially damaged labrum and articular cartilage at the abnormally loaded acetabular rim remain within the main weight-bearing zone with both of these surgical procedures. This may be one main cause of inferior results reported with Chiari osteotomies in adolescents who are more than fourteen years old or in patients with a torn labrum. Augmentation procedures are not commonly indicated in adolescents and young adults currently, but may be considered in acetabula with a very short roof or in hips in which the acetabular radius is smaller than the radius of the femoral head.

Three types of juxta-acetabular osteotomies for acetabular reorientation are currently in wider use. These osteotomies include (1) a spherical or rotational osteotomy, (2) a triple osteotomy, and (3) the Bernese peri-acetabular osteotomy. The principle of the spherical or rotational osteotomy was described by Wagner in Europe and by Ninomiya and Tagawa in Japan. The osteotomy is performed with a curved chisel close to the subchondral bone. The advantage is that it provides a mobile fragment. However, this osteotomy lacks the potential for medialization of the hip center and may become intra-articular in the caudal portion of the acetabulum. Tönnis et al. popularized a triple osteotomy with complete osteotomies of the iliac, ischial, and pubic bone. Initial fixation included osteosynthesis of the iliac and pubic bone. The recommended postoperative treatment was immobilization in a spica cast for several weeks. With the current technique, the ischial spine with the attached sacrospinal ligament remains attached to the pelvic segment, and fixation of the acetabular fragment has become easier without the need for postoperative cast immobilization. The Bernese peri-acetabular osteotomy was popularized in 1988 by Ganz et al. and was first performed in 1984. This osteotomy has the advantage of creating a polygonal acetabular fragment while leaving the posterior column intact, by an incomplete osteotomy of the ischium. There is immediate postoperative stability since the pelvic ring is not disrupted. There is no deformity of the true pelvis in young female patients, allowing for childbirth through vaginal delivery after surgical correction. The mobile acetabular fragment allows adequate corrections, even for severe deformities, and has the potential for an optimal medialization of the acetabular center of rotation. Fixation of the

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osteotomized fragment can be done typically with screws only in the acetabular fragment, and postoperative care requires only partial weight-bearing on crutches without the need for a cast. Thus, the Bernese periacetabular osteotomy has become our preferred treatment for correction of acetabular dysplasia in hips with a closed triradiate growth plate.

**Treatment of the Abnormal Femoral Side**

Developmental dysplasia of the hip also affects the femoral head side. There is a wide range of deformities of the proximal part of the femur from a subtle oval-shaped deformity of the femoral head to aberrant torsion or orientation of the femoral neck, to more severe abnormalities of the entire proximal part of the femur.

**Additional Intertrochanteric Osteotomy**

Generally, a concomitant intertrochanteric osteotomy is only indicated in approximately 10% of all patients undergoing periacetabular osteotomy. The most common indications for an additional intertrochanteric osteotomy are (1) an extreme valgus angulation of the femoral neck with a fovea alta, (2) joint incongruence following acetabular reorientation (typically seen with more severe femoral head deformities), and (3) restoration of a normal femoral neck-shaft angle after a previous varus osteotomy of the proximal part of the femur.

**Extreme Valgus with Fovea Alta**

In dysplastic hips, an abnormal valgus femoral neck configuration may be associated with a fovea alta, with the fovea capitis femoris more cranial than in a normal hip joint and the ligamentum capitis femoris articulating with the weight-bearing area of the acetabular cartilage (Figs. 1-A and 1-B). A fovea alta further reduces the weight-bearing zone between the cartilaginous joint surfaces of the femoral head and the acetabulum, aggravating the underlying dysplastic pathomorphology.

**Joint Incongruency After Periacetabular Osteotomy**

Primary or secondary deformity of the femoral head leads to numerous instantaneous centers of rotation that depend on the actual surface under stress, which varies with the relative position of the acetabulum and femur. This can be seen on an abduction radiograph made either preoperatively or intraoperatively after periacetabular osteotomy. If the abduction radiograph shows improved hip congruency, a varus osteotomy should be considered (Figs. 2-A, 2-B, and 2-C).

**Femoral Neck-Shaft Realignment After a Previous Proximal Femoral Varus Osteotomy**

If residual hip dysplasia after a previous proximal femoral varus osteotomy needs acetabular correction, a periacetabular osteotomy may lead to restricted hip abduction, flexion, and internal rotation. A corrective rotational valgus intertrochanteric osteotomy can then minimize anterolateral...
A twenty-four-year-old man with residual dysplasia after previous shelf acetabuloplasty and varus femoral osteotomy of the right hip. **Fig. 3-A** Preoperative anteroposterior radiograph. **Fig. 3-B** Anteroposterior radiograph made after a periacetabular osteotomy was performed with resection of the shelf acetabuloplasty and a concomitant intertrochanteric valgus femoral osteotomy. **Fig. 3-C** Radiograph of the hip made ten years postoperatively showing an excellent clinical result.

Surgical correction in-...sion (Fig. 4 and Appendix). To provide a rough guideline for the amount of bone to be resected, the goal of internal rotation of 30° in 90° of flexion seems appropriate14. Optionally, major unstable labral tears can be debrided or repaired with suture anchors15.

**Surgical Considerations and Our Preferred Technique**

The patient is placed in a supine position with the hemipelvis and leg of the affected side steriley prepared and draped. The skin incision is a shortened ilioinguinal incision. The incision starts laterally at the intersection between the medial and middle third of the iliac wing and extends about 5 cm medial to the anterior superior iliac spine. The incision is placed about 2 cm distal to the iliac crest (Fig. 5-A). This type of incision is cosmetically superior to the modified Smith-Petersen incision. The sartorius muscle (medial) is separated from the tensor fascia lata muscle (lateral), exposing the direct origin of the rectus femoris muscle from the anterior inferior iliac spine. The abdominal wall muscles are sharply dissected off the iliac crest, and the iliac muscle is mobilized from the iliac wing. The origin of the sartorius muscle together with the inguinal ligament is sharply dissected, mobilized, and medially retracted from the anterior superior iliac spine with the preferred technique of periacetabular osteotomy is shown. Typically, dysplastic hips present with an aspherical femoral head (asterisk) (left). Before periacetabular osteotomy, this decreased head-neck offset is compensated for by the diminished anterior acetabular coverage. After proper reorientation, femoroacetabular impingement may become apparent in deep flexion and internal rotation (arrow) (center). Iatrogenic acetabular overcoverage can worsen this impingement. Through an intraoperative arthrotomy, the femoroacetabular impingement can be assessed (right). If necessary, a concomitant osteochondroplasty of the femoral neck can be performed (arrows). (Reproduced, with modification, from Springer Science + Business Media: Albers CE, Steppacher SD, Ganz R, Tannast M, Siebenrock KA. Impingement adversely affects 10-year survivorship after periacetabular osteotomy for DDH. Clin Orthop Relat Res. 2013 Jan 25. [Epub ahead of print]. Reproduced with permission.)

**Prevention of Femoroacetabular Impingement**

Hips with developmental dysplasia often have a decreased femoral head-neck offset16. With the acetabular reorientation typically anterosuperior, head coverage will be increased, which potentially initiates painful femoroacetabular impingement against the proximal part of the femur with reduced femoral head-neck offset (Fig. 4). Therefore, in hips with limited internal rotation (<30°), the joint should be opened, visually inspected, and analyzed for impingement with the hip flexed and internally rotated20. The arthrotomy allows for inspection of the acetabular labrum as well as the assessment of the anatomy of the femoral head-neck junction. An osteochondroplasty with removal of the aspherical portion of the femoral head-neck junction should be done (Fig. 4 and Appendix). To provide a rough guideline for the amount of...
iliacus and psoas muscles (Fig. 5-B). As a further modification from the previously used technique, the two origins of the rectus femoris muscle are left intact and the interval between the rectus muscle (lateral) and the iliopsoas muscle (medial) is dissected and bluntly opened with scissors. The iliocapsularis muscle is sharply separated from the capsule laterally and mobilized medially, together with the iliopsoas muscle. A Hohmann retractor is placed into the superior pubic ramus 2 to 3 cm medial to the pubic eminence. With use of scissors, the infra-articular space is spread open strictly following the contour of the calcar directly on the intact capsule (Fig. 5-B). With the tip of the scissors, the ischial bone can be palpated beneath the posterior horn. With a specially designed curved chisel, the first ischial osteotomy is done. The osteotomy of approximately 4 to 5 cm is an incomplete cut of the ischium. Next, two blunt retractors are placed around the superior aspect of the pubic bone to protect the soft tissues and perform the pubic osteotomy (Fig. 5-C). At the level of the anterior superior iliac spine, partial elevation of the abductor muscles from the outside of the iliac wing is done to place a blunt retractor for protection of the abductor muscles. The periosseum and obturator internus muscles are bluntly dissected off the quadrilateral plate, and another blunt curved retractor is placed on the quadrilateral surface close to the ischial spine to further retract the soft tissues medially. With use of an oscillating saw, an oblique iliac osteotomy is performed at the level of the anterior superior iliac spine (Fig. 5-C). This osteotomy ends 1 to 2 cm lateral to the pelvic rim. From there, an osteotomy angled approximately 110° distally in regard to the previous horizontal cut of the ilium. This osteotomy is performed with a
TABLE I Minimum Ten-Year Survivorship of the Hip After Surgical Treatment of Developmental Dysplasia with Conversion to Total Hip Arthroplasty as the End Point

<table>
<thead>
<tr>
<th>Study</th>
<th>Technique</th>
<th>Duration of Follow-up* (yr)</th>
<th>No. of Hips</th>
<th>Age* (yr)</th>
<th>Survival Rate (%)</th>
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</thead>
<tbody>
<tr>
<td>Siebenrock et al. 10</td>
<td>Periacetabular</td>
<td>11.3 (10-14)</td>
<td>75</td>
<td>29 (13-56)</td>
<td>82</td>
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<tr>
<td>Kralj et al. 27</td>
<td>Periacetabular</td>
<td>12 (7-15)</td>
<td>26</td>
<td>34 (18-50)</td>
<td>85</td>
</tr>
<tr>
<td>Flecher et al. 28</td>
<td>Periacetabular</td>
<td>12 (2-19)</td>
<td>33</td>
<td>32 (18-47)</td>
<td>74</td>
</tr>
<tr>
<td>Steppacher et al. 29</td>
<td>Periacetabular</td>
<td>20.4 (19-23)</td>
<td>75</td>
<td>29.3 (13-56)</td>
<td>61</td>
</tr>
<tr>
<td>Matheney et al. 40</td>
<td>Periacetabular</td>
<td>9 ± 2.2</td>
<td>135</td>
<td>23 (10-44)</td>
<td>84</td>
</tr>
<tr>
<td>Ito et al. 36</td>
<td>Periacetabular</td>
<td>11 (5-20)</td>
<td>158</td>
<td>32 (12-56)</td>
<td>96</td>
</tr>
<tr>
<td>Nakamura et al. 34</td>
<td>Rotational</td>
<td>13 (10-23)</td>
<td>145</td>
<td>28 (11-52)</td>
<td>95</td>
</tr>
<tr>
<td>Takatori et al. 41</td>
<td>Rotational</td>
<td>13 (10-18)</td>
<td>28</td>
<td>33 (19-40)</td>
<td>96</td>
</tr>
<tr>
<td>Takatori et al. 39</td>
<td>Rotational</td>
<td>19.8 (15-22)</td>
<td>15</td>
<td>24.3 (20-28)</td>
<td>100</td>
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<tr>
<td>Nozawa et al. 48</td>
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<td>11.4 (10-15)</td>
<td>50</td>
<td>31.8 (13-53)</td>
<td>98</td>
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<tr>
<td>Yasunaga et al. 39</td>
<td>Rotational</td>
<td>11 (8-15)</td>
<td>61</td>
<td>35 (13-58)</td>
<td>100</td>
</tr>
<tr>
<td>Guille et al. 31</td>
<td>Triple</td>
<td>12 (10-16)</td>
<td>11</td>
<td>14 (11-16)</td>
<td>91</td>
</tr>
<tr>
<td>Van Hellemond et al. 35</td>
<td>Triple</td>
<td>15 (13-20)</td>
<td>51</td>
<td>28 (14-46)</td>
<td>88</td>
</tr>
<tr>
<td>Janssen et al. 36</td>
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<td>35</td>
<td>39 (24-57)</td>
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<tr>
<td>Schramm et al. 33</td>
<td>Wagner spherical</td>
<td>23.9 (20-29)</td>
<td>22</td>
<td>24.4 ± 9.7</td>
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<tr>
<td>Zagra et al. 39</td>
<td>Wagner spherical</td>
<td>23.1 (21-27)</td>
<td>10</td>
<td>19.3 (17-27)</td>
<td>100</td>
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*Continuous data are expressed as the mean, with the range in parentheses if available, or the standard deviation.

Intraoperative Evaluation

Intraoperative evaluation can most accurately and efficiently be done by examining an anteroposterior pelvic radiograph. The tube-to-film distance is approximately 1.2 m in our department. Recommendations for defining the so-called ideal correction parameters can only be given in ranges and not to the exact degree. The parameters and recommended goals are (1) a lateral center-edge angle between 20° and 35°, preferably between 25° and 30°; (2) an anterior center-edge angle between 0° and 10°, preferably in the upper range; (3) head medialization with a distance between the medial aspect of the femoral head and the ilioschial line of <10 mm; (4) restoration of the Shenton line; (5) a weight-bearing dome centered over the head; (6) antversion of the acetabulum as defined by the absence of a cross-over sign and the outlines of the anterior and posterior rim meeting at the lateral acetabular edge; and (7) restoration of hip joint congruency.

Persistent joint incongruity after acetabular reorientation requires intraoperative functional radiographs made with the hip in abduction or adduction to decide whether an intertrochanteric osteotomy is necessary. After obtaining a satisfactory correction, we judge the hip...
motion, especially flexion and internal rotation. Although there is no agreement regarding the definition of decreased internal rotation, internal rotation that is only between 15° and 30° should lead one to further search for its cause. Exclusion of intra-articular femoroacetabular impingement or extra-articular impingement against the anterior inferior iliac spine is recommended in a recent series of ninety patients, a femoral head-neck offset correction was performed in 57% of the hips after acetabular reorientation through a periacetabular osteotomy.

**Review of the Literature**

There is evidence that acetabular reorientation can decelerate joint degeneration. The long-term results (ten to almost thirty years) for all three types of juxta-acetabular osteotomies are summarized in Table I. The survivorship of the hip has been reproducibly shown to be approximately 90% after ten years and 60% to 70% after twenty years, independent of the reorientation technique. The long-term reports of the early series typically involved heterogeneous patient cohorts, including patients with advanced age and/or joint degeneration. In a follow-up study with a more homogenous patient cohort at our institution, a good clinical result without progression of osteoarthritis was achieved in 90% of the patients at a minimum ten-year follow-up interval. Follow-up studies that have shown survivorship of up to 100% typically have involved a nonconsecutive series of patients, exclusive of patients with previous surgical procedures on the hip, low numbers of patients, or a substantial percentage of patients lost to follow-up. The natural history of hip dysplasia is not as good. Several common negative predictors influencing the long-term outcome after acetabular reorientation for developmental dysplasia of the hip were identified. These include mainly demographic or independent preoperative factors such as advanced age, low preoperative functional hip scores, a body mass index of >25 (kg/m²), preexisting early osteoarthritis, a preoperative limp, evidence of a labral tear with pain in flexion and internal rotation, and preoperative femoral head subluxation.

Postoperative lateral acetabular undercoverage and excessive acetabular anteversion can lead to persistent static overload of the lateral and/or the anterior acetabular rim with subsequent degeneration. Postoperative lateral overcorrection and acetabular retroversion have been associated with decreased hip survivorship because of iatrogenic postoperative femoroacetabular impingement between the overcorrected acetabulum and the proximal part of the femur. A previous femoral head-neck offset correction or, if necessary, an intraoperative offset correction in hips with an aspherical head-neck junction improves the ten-year survivorship. In conclusion, improper acetabular reorientation, specifically incorrect acetabular version and a concomitant persistence of an aspherical femoral head-neck junction, needs to be included as a risk factor for a less favorable outcome.

**Overview**

The appropriate surgical treatment of hip dysplasia after closure of the triadiate cartilage is a reorientation of the entire acetabulum. Among the different surgical techniques for acetabular reorientation, periacetabular osteotomy has become the gold standard. It provides the largest reorientation potential with inherent stability because of its polygonal shape without changing the dimensions of the birth canal. There is increasing evidence that the natural degeneration in dysplastic hips can be decelerated by periacetabular osteotomy. The survival rate of the hip after acetabular reorientation is approximately 90% after ten years and 60% to 70% after twenty years. Careful patient selection, an optimal acetabular reorientation, and a concomitant osteochondroplasty of an aspherical femoral head-neck junction may lead to improved long-term results.

**Appendix**

Figures showing radiographs of a twenty-five-year-old woman with residual deformity from Legg-Calvé-Perthes disease who had an excellent result after a periacetabular osteotomy, surgical hip dislocation with trimming of the femoral head-neck junction, and lengthening of the femoral neck as well as radiographs of a female patient with developmental dysplasia of the hip who had correction of a decreased femoral head-neck offset with an arthroplasty are available with the online version of this article as a data supplement at jbjs.org.

**References**


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