SUBSPECIALTY PROCEDURES

REORIENTATIONAL PROXIMAL FEMORAL OSTEOTOMIES FOR CORRECTION OF HIP CONTRACTURES IN CHILDREN WITH ARTHROGRYPOSIS

Harold Jacob Pieter van Bosse, MD

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Introduction

Reorientational osteotomy of the proximal part of the femur for children with arthrogryposis repositions the various arcs of hip motion into a more functional sphere of motion, addressing the hip contractures that otherwise are the main mechanical impediments to ambulation.

The goal of the reorientational osteotomy is to align the lower extremity with the body, leaving the femoral-acetabular relationship unchanged. This is accomplished by way of an intertrochanteric wedge-type osteotomy and using a 90° cannulated hip blade plate. Prior to the osteotomy, the proximal fragment is prepared by first positioning the hip in its usual resting position, as dictated by the contractures. A seating chisel is used to cut the track for the blade plate in the proximal femoral metaphysis and neck, parallel to the coronal and transverse planes of the pelvis regardless of the femur's position relative to the body. Compared with the usual track of the implant's blade, which is centered within the femoral neck on the lateral view of the proximal part of the femur, in this procedure the blade-plate track is usually quite oblique, often with bicortical purchase of the blade as it penetrates the posterior femoral neck. The first osteotomy cut is then made at the intertrochanteric level, parallel to the seating chisel. A second osteotomy is made in the distal fragment to square it with the femoral shaft. The 2 osteotomy surfaces are then joined together, with acute derotation of the distal fragment as clinically needed. The blade of the 90° blade plate is impacted into the proximal fragment, and then aligned and affixed to the femoral shaft. A Petrie cast is applied, in both unilateral and bilateral cases, unless a simultaneous open reduction of a congenitally dislocated hip had been done on the contralateral side, in which case a bilateral hip spica cast is applied.

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Indications & Contraindications

Indications

- Patients, usually children, 12 months or older, with multiplanar, arthrogrypotic hip contractures that restrict sitting and/or potential ambulatory abilities. There is no upper age limit; we have done this procedure with good results in teenagers.
- Patients with dislocated hips that are not suitable for relocation, because the child is considered too old or because of extreme preoperative stiffness of the hip, who demonstrate lower limb positioning due to hip contractures that is functionally limiting.
- Hips with a severely limited total flexion-extension arc that are not appropriately positioned for sitting and are recalcitrant to soft-tissue releases may benefit from the procedure specifically to position the lower extremities for more comfortable seating.

Contraindications

- Hips with isolated mild or moderate flexion or flexion-abduction contractures that can be adequately addressed by a percutaneous anterior hip release. See Step 3 below for details on the percutaneous anterior hip release.
- Hips with an isolated mild extension contracture (lack of flexion) that can be adequately addressed with a posterior hip release.
- Hips with isolated rotational limitations that can be adequately addressed by femoral shaft derotational osteotomies.
- There are no contraindications related to the perceived ambulatory abilities of the infant or child, as we have found time and again that children will exceed expectations. Similarly, we do not conduct any sort of muscle strength testing, both because it is difficult to do so in infants and young children and because even older children with only “a flicker” of hip motion often develop/acquire better hip strength once the limb is more optimally positioned. This may be related to a more optimal positioning of the muscle insertion sites after the reorientation.

Step 1: Preoperative Assessment

Determine hip range of motion clinically and obtain radiographs to confirm that the hips are located and there are no unusual structural abnormalities.

- Position the patient supine, flexing 1 hip just enough to nearly flatten the lumbar lordosis in order to reveal any flexion contractures of the contralateral hip. Check that the anterior superior iliac spines are on the same level, to correct for any pelvic rotation. Our protocol is to record hip flexion, extension, frog-leg and regular abduction, and hip internal and external rotation with the hip flexed 90° or as close to 90° as the hip will allow. Also evaluate hip internal and external rotation with the hips as extended as possible (Video 1).
- Be aware that the flexion contractures nearly always have an abduction component. Also, when the contralateral hip is fully flexed, the pelvis will become oblique, with the hemipelvis on the flexed side moving superiorly. For this reason, the hip being extended should be adducted with respect to the body axis to bring it orthogonal to the transverse plane of the pelvis and truly demonstrate the flexion contracture (Fig. 1).
- If the contractures are primarily flexion or flexion-abduction contractures, and there is a tight cord extending inferiorly from the anterior superior iliac spine, the patient may benefit from a percutaneous anterior hip release. This soft-tissue release alone may be adequate treatment for small to moderate contractures. It can also be an adjunct to the reorientational osteotomy, as a way to decrease the extent of correction needed to be achieved with the osteotomy as well as increase the total arc of motion.
- Obtain supine anteroposterior and frog-leg pelvic radiographs to confirm that the hip or hips are located and there are no unusual structural abnormalities. The ossific nucleus in children with arthrogryposis multiplex congenita is often late in developing and sometimes is still not clearly visible at 18 months of age. An arthrogram is occasionally needed at the start of the operative procedure to verify that both hips are located.
- Evaluate the feet for congenital deformities. Children with arthrogryposis often have clubfoot or congenital vertical talus deformities. It is convenient to do more than one procedure in the operating room at a time, if possible, and important to limit exposing young children repeatedly to general anesthetics. Therefore, when applicable, serial cast treatment of foot deformities should be done preoperatively so that percutaneous Achilles tenotomies and/or open realignments of the talonavicular joint can be done at the time of the hip surgery.

Fig. 1

Video 1 Preoperative examination to determine the range of hip motion.

Fig. 1 Patient positioning for accurate measurement of hip flexion and extension. Flex one hip until the lumbar lordosis is nearly flattened. Then adduct the contralateral hip so that the extremity is orthogonal to the pelvis, not the patient's body axis, prior to extending the hip. Note that, when the first hip is flexed, the pelvis will become oblique with the flexed side high.

Step 2: Patient Positioning and Draping

Position the patient supine with a bump at the sacrum, and drape to allow access to both hips simultaneously.

- The procedure is done with the patient under general anesthesia, with a caudal or epidural block as appropriate. A “type and screen” is performed, but blood transfusions are needed in <5% of cases. No arterial or central line is needed in healthy patients. A radiolucent operating table is used; I prefer a Jackson flat-style table for an unobstructed fluoroscopic view.
- Position the patient supine with a transverse radiolucent bump at the level of the sacrum, both to improve exposure and to allow fuller hip extension. I prefer a “sticky bump,” an intravenous fluid bag wrapped first with an operating field towel and then wrapped circumferentially with adhesive tape with the adhesive side outward. The bump will then stick to the patient and the operating room table, making it less likely to displace during the procedure, even if the patient is being manipulated.
- Place a Foley catheter. In bilateral cases, bring the catheter anteriorly, then over the middle of the chest, and then over one of the shoulders (Fig. 2).
- Prepare the skin as usual, up to the umbilicus proximally and as far laterally and posteriorly at the hips and buttocks as possible. Include the entire perineum as well as the Foley catheter in bilateral cases. The entire lower extremity will be included in the field.
- Drape the patient for a bilateral procedure with a single split or “U” drape, starting inferiorly/posteriorly just anterior to the anus. Then proceed along bilaterally inferior to the buttocks and then as posteriorly as possible along the hips and pelvis while ascending the drape to the waist. Place another drape transversely just superior to the anterior superior iliac spines, and then place a narrowly folded towel, running vertically, to cover the Foley catheter and the perineum. This allows the most access to both hips simultaneously and also allows sufficient exposure if the contralateral hip requires an open reduction (Fig. 2 and Video 2).

Fig. 2

Fig. 2 Draping of a 5-year-old girl about to undergo bilateral procedures for bilateral hip extension contracture. **Left image** The Foley catheter is brought proximally up the midline, and it is prepared into the field. **Center image** After draping with towels, adhesive draping material is used to seal the edges. **Right image** The operative field, once the operative drapes have been applied. There is good access to the hip areas bilaterally. **Video 2** Draping the patient for the procedure.

Step 3: Initial Percutaneous Anterior Hip Release

Perform an initial anterior hip release for patients with a palpable soft-tissue flexion contracture.

- Fully flex the contralateral hip; then extend and adduct the ipsilateral hip. If a tight cord-like structure originating at the anterior superior iliac spine can be readily palpated, a simple anterior hip release may provide the patient with an important gain in initial extension range (Fig. 3-A). The cord is the conjoined tendon of the sartorius and the tensor fasciae latae, which can create a flexion-abduction contracture.
- Make a stab incision just medial to the conjoined tendon, approximately 1 to 2 cm distal to the anterior superior iliac spine (Fig. 3-B).
- Turn the scalpel laterally and transect the conjoined tendon (Fig. 3-C).
- Continue laterally, using the scalpel blade to palpate deep to the fascia lata. Incrementally incise the fascia lata, ending just superior to the greater trochanter (Figs. 3-D and 3-E).

Fig. 3-A

Fig. 3-B

Fig. 3-C

Fig. 3-D

Fig. 3-E

Figs. 3-A through 3-E Steps of the percutaneous anterior hip release for palpable anterior hip contractures. **Fig. 3-A** Flexion of the left hip with extension of the right to demonstrate the contracting band of the conjoined tendon of the sartorius and tensor fasciae latae, emanating from the right anterior superior iliac spine. The greater trochanter is outlined laterally, and the anterior superior iliac spine is outlined anteriorly with the conjoined tendon extending inferiorly. (Note that the monitoring leads were placed in preparation for a spinal procedure performed immediately after the hip releases and are not related to the anterior hip release.)

Fig. 3-B A stab incision is made for the percutaneous anterior hip release, just medial to the conjoined tendon of the sartorius and tensor fasciae latae, 1 to 2 cm distal to the anterior superior iliac spine.

Fig. 3-C The conjoined tendon is transected while the structure is palpated through the skin.

Fig. 3-D The surgeon continues laterally, transecting the fascia lata, ending just superior to the greater trochanter.

Fig. 3-E Improved hip extension after the percutaneous anterior hip release. No functional hip flexor tendons were transected, so hip flexion strength should be preserved.

- If a large flexion contracture is still apparent, palpate deeply while cycling the hip into extension to feel whether the rectus femoris is tight. If it is, it can be transected off the anterior inferior iliac spine through the same incision, sweeping from medial to lateral.
- If palpation indicates a tight structure just medial to where the sartorius and tensor fasciae latae conjoined tendon were situated, this is the fascia overlying the iliacus muscle. This fascia can be incised as well, but use extreme caution as the anterior hip neurovascular bundle lies just medially. To stay safe, I generally incise only 5 to 10 mm of the iliacus fascia because it is unlikely that the neurovascular bundle can be palpated. To date, I have not performed this procedure in an open fashion, but I have always avoided neurovascular injury, primarily by not straying >5 to 10 mm past the lateral edge of the iliacus fascia.
- Obtain hemostasis with 5-mm-square pieces of thrombin-soaked Gelfoam (Pfizer), along with direct pressure or full hip flexion. Insert as many Gelfoam pieces into the incision as needed, anywhere from none to 5.

Step 4: Surgical Approach to the Proximal Part of the Femur

Make a standard approach to the lateral aspect of the proximal part of the femur.

- Make a longitudinal incision of 5 to 8 cm, with the length depending on the child's age, starting just inferior to the palpable greater trochanter and extending distally (Fig. 4).
- Incise the fascia lata in line with the skin incision, extending the exposure proximally and distally under the skin (Video 3).
- Make a small incision in the vastus lateralis fascia as posteriorly as possible. Through this rent, place small Hohmann retractors subperiosteally anterior and posterior to the femur, with a goal of sweeping all of the vastus lateralis muscle anteriorly.
- Extend the vastus lateralis fascia incision distally the length of the skin incision and proximally to the vastus ridge. Then release the vastus lateralis fascia transversely at the vastus ridge, allowing the entire vastus lateralis muscle to be subperiosteally elevated anteriorly.
- In many cases, the vastus lateralis muscle is nonexistent, replaced by fibroadipose tissue, or the fascia lata and vastus lateralis tissues are confluent. In those cases, the fascia lata incision is essentially deepened down to the periosteal level.

Fig. 4

Fig. 4 A 5 to 8-cm longitudinal incision is made starting just inferior to the greater trochanter for the approach to the proximal part of the femur.

Video 3 Surgical approach and exposure of the lateral aspect of the femur.

Step 5: Blade-Plate Positioning

Position a guidewire for the appropriate correction; then cut a track for the blade plate with a seating chisel.

- Place a “pelvic axis wire” on the skin across the pelvis by spanning a wire or Steinmann pin between the 2 anterior superior iliac spines and holding it in place with a sterile operative adhesive dressing (Fig. 5-A). This marker will be visible with fluoroscopy and provide a positioning landmark.
- Place the hip in its usual resting position as dictated by the hip contractures. This is a flexed, abducted, and externally rotated position in the typical patient with arthrogryposis, although the procedure is applicable to any of the multiplanar contracture combinations that we have encountered.
- Place a guidewire from the cannulated hip blade-plate set against the most lateral aspect of the proximal part of the femur, as seen on a posteroanterior fluoroscopic image (Fig. 5-B). The wire should be aligned parallel to the pelvic axis wire in the coronal plane on fluoroscopy and parallel to the transverse plane of the pelvis visually. The wire should be positioned proximally on the femur to traverse the maximal length of the femoral neck. Advance the guidewire until it is just lateral to the proximal femoral epiphysis or it has penetrated a far cortex (Fig. 5-C). Because of the external rotation contracture common to many arthrogryptic hips, the guidewire will often have an oblique trajectory, anatomically entering the proximal part of the femur anterolaterally and exiting the femoral neck posteroproximally (Figs. 5-D and 5-E, and Video 4).

Fig. 5-A

Fig. 5-B

Fig. 5-C

Fig. 5-D

Fig. 5-E

Figs. 5-A through 5-F Positioning of the guidewire for the cannulated blade plate, and cutting of the track for the blade. **Fig. 5-A** A stout wire placed from one anterior superior iliac spine to the other represents the pelvic axis and is known as the “pelvic axis wire.”

Fig. 5-B The guidewire for the cannulated blade plate is positioned on the lateralmost aspect of the femur, parallel to the pelvic axis wire, at a level where the wire will have the longest trajectory within bone.

Fig. 5-C A guidewire for the cannulated blade plate is drilled into the proximal part of the femur, parallel to the pelvic axis wire in all planes.

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Figs. 5-D and 5-E Because of the externally positioned proximal part of the femur, the guidewire will have an oblique pathway, often from anterior-lateral to posterior-proximal, achieving bicortical fixation. (Fig. 5-D reproduced from: van Bosse HJ, Saldana RE. Reorientational proximal femoral osteotomies for arthrogryptic hip contractures. J Bone Joint Surg Am. 2017 Jan 4;99[1]:55-64.)

Video 4 Positioning and cutting the track for the blade plate.

- Confirm the position of the wire under multiple fluoroscopic projections to ensure that the wire has the best bone purchase, despite hip positioning.
- Choose the appropriately sized seating chisel; the width should be slightly less than the diameter of the femoral neck. Place the seating chisel over the wire with the blade rotated parallel to the transverse plane of the pelvis while the hip is still in its original “resting” position. This will set the maximal hip extension to approximately 0° postoperatively (Fig. 5-F). In cases of extremely severe hip flexion contracture (90°), the seating chisel will be oriented perpendicular to the vastus ridge. (If the patient has a hip extension contracture, and the goal is to increase hip flexion for sitting, then flex the hip maximally and rotate the seating chisel so that the blade is perpendicular to the transverse plane of the pelvis. This will then set the position for maximal hip flexion of approximately 90° postoperatively.)
- Advance the seating chisel by impacting it with a mallet until it is just lateral to the proximal femoral physis or has penetrated the far cortex. When doing this, the chisel should be advanced only about 10 mm at a time and then pounded back to loosen it prior to advancing it further.
- Note the depth of the seating chisel inside the bone to determine the length of blade needed for the implant. Pound back the seating chisel 5 to 10 mm to ensure easy removal after the osteotomies.

Fig. 5-F

Fig. 5-F The cannulated seating chisel is advanced to cut the track for the blade plate. The seating chisel should be oriented with the blade parallel to the transverse plane of the pelvis in order to correct the flexion contracture to 0°. (Reproduced from: van Bosse HJ, Saldana RE. Reorientational proximal femoral osteotomies for arthrogrypotic hip contractures. *J Bone Joint Surg Am.* 2017 Jan 4;99[1]:55-64.)

Step 6: Wedge-Shaped Intertrochanteric Osteotomy

Perform 2 intertrochanteric osteotomy cuts to provide cut surfaces that, when joined together, will position the lower extremity optimally.

- Make a proximal osteotomy cut with a sagittal saw parallel and 5 to 8 mm inferior to the seating chisel surface (Figs. 6-A and 6-B). Do not make the proximal osteotomy too close to the seating chisel as this may increase the risk of the blade plate cutting out. Medially, the thick periosteum and iliopsoas tendon insertion will need to be stripped off the bone in order to free the 2 fragments. Be careful to not transect this tissue or active hip flexion will be compromised; instead elevate the iliopsoas as an intact sleeve with the periosteum, allowing it to reattach spontaneously.
- Create a second osteotomy cut in the distal fragment, perpendicular to the shaft, so that a wedge of bone is removed (Fig. 6-C).
- Elevate the periosteum of the distal fragment circumferentially to allow for proper positioning and derotation of the limb. My goal is usually for the limb to have equal internal and external rotation at the end of the operation. If it is too difficult to approximate the 2 osteotomy surfaces, the distal fragment can be shortened by 5 mm.
- Verify that the 2 surfaces can be satisfactorily apposed with appropriate derotation of the inferior fragment prior to affixing the blade plate (Video 5).

Fig. 6-A

Fig. 6-B

Fig. 6-C

Figs. 6-A, 6-B, and 6-C Creation of the proximal and distal bone cuts that will define the wedge-shaped intertrochanteric osteotomy.

Figs. 6-A and 6-B The proximal osteotomy is parallel and 5 to 8 mm distal to the blade of the seating chisel. The distal osteotomy is perpendicular to the shaft of the distal fragment, so that the 2 cuts meet medially as the apex of the wedge. (Fig. 6-A reproduced from: van Bosse HJ, Saldana RE. Reorientational proximal femoral osteotomies for arthrogryptic hip contractures. J Bone Joint Surg Am. 2017 Jan 4;99[1]:55-64.)

Fig. 6-C The second osteotomy cut is perpendicular to the shaft of the distal fragment.

Video 5 Two-level osteotomy at the intertrochanteric level.

Step 7: Applying the Blade Plate and Closure

Impact the blade plate into the proximal fragment and secure it to the distal fragment.

- Remove the seating chisel, leaving the guidewire inside the track for the blade plate. If there is a spike of bone laterally on the proximal fragment, trim it to allow full seating of the implant. I use a cannulated hip blade plate with a 90° angle, with proximal offset, and a 3-screw-hole plate segment (Fig. 7-A and Video 6). I use the standard offset distance, not the reduced offset, although the appropriate offset is determined by the individual surgeon. Impact the blade of the implant fully into the proximal fragment, over the guidewire. Be careful to prevent flexion or extension rotation of the implant when advancing it (Fig. 7-B).
- Approximate the femoral shaft to the plate segment of the implant, and carefully verify that the lower limb is in neutral rotation in relation to the pelvis. Then secure the plate to the femoral shaft with the appropriate cortical bone screws. I usually fill only the proximal 2 screw holes, as this usually provides sufficient fixation to the shaft and makes it easier to remove the plate later (Figs. 7-C and 7-D).
- If possible, place a cancellous screw through the implant into the proximal fragment for more secure fixation of the proximal fragment.

Fig. 7-A

Fig. 7-B

Fig. 7-C

Fig. 7-D

Figs. 7-A through 7-F Applying the blade plate to approximate the osteotomy surfaces and reorient the hip. **Fig. 7-A** Cannulated 90° blade plate with an offset and a 3-hole plate segment (Smith & Nephew).

Fig. 7-B Cannulated blade plate impacted into the proximal fragment.

Figs. 7-C and 7-D Femoral shaft affixed to the blade plate by way of cortical screws. Note that the femur was derotated so that the knee is now facing directly anteriorly with respect to the body. (Fig. 7-C reproduced from: van Bosse HJ, Saldana RE. Reorientational proximal femoral osteotomies for arthrogryptic hip contractures. J Bone Joint Surg Am. 2017 Jan 4;99[1]:55-64.)

Video 6 Insertion of the blade plate and fixation of the osteotomy site.

- With large flexion contractures, an anterior bone spike will be created because of the oblique osteotomy relative to the femoral shaft. Trim this spike parallel to the anterior surface of the implanted plate so that the spike does not impinge on the acetabulum or neurovascular structures with flexion (Figs. 7-E and 7-F).
- Irrigate the surgical site; then massage vancomycin powder into the soft tissues if appropriate. With most of these procedures, we place a subcutaneous catheter (ON-Q; Halyard Health) to infuse analgesics postoperatively.
- If there is a healthy vastus lateralis, reapproximate it over the implant; otherwise, make no attempt to cover the implant. Do not reapproximate the fascia lata as doing so will often place it under tension, limiting motion. Close the skin in 3 layers with absorbable suture, using a running stitch in the subcutaneous fascia, then interrupted buried subcutaneous suture stitches, and finally a running subcuticular stitch. Our rate of wound dehiscence and infection for this procedure is no greater than that for any other procedure.
- No drain is used in an uncomplicated case.
- Molds of the patient's legs are made to fabricate the knee-ankle-foot orthoses (KAFO), so that the brace will be ready in 6 weeks when the cast is removed. The KAFO will usually have ratcheting knee hinges to help support the knees, which are usually affected by flexion contractures.

Fig. 7-E

Fig. 7-F

Figs. 7-E and 7-F When there is a substantial correction of a flexion contracture with the osteotomy, a large anterior bone spike will result from the first bone cut. This should be trimmed to prevent osseous impingement with flexion or the possibility of neurovascular impingement. **Fig. 7-E** The bone spike and the proposed resection cut (black line). **Fig. 7-F** After the bone spike has been removed.

Step 8: Postoperative Management

Apply a Petrie cast, and instruct the parents on how to maintain hip motion.

- Obtain anteroposterior and frog-leg pelvic views to confirm osteotomy positioning and fixation. This provides a record of the initial postoperative appearance, which is helpful when assessing postoperative stability after these unusual osteotomies.
- Apply a Petrie cast (long leg casts down both lower extremities connected by a bar between the ankles) with the each hip abducted approximately 20° to 25° and rotated into a neutral position (Fig. 8).
- Mobilize the patient in a reclining wheelchair with elevated leg rests, to gradually increase hip flexion. Instruct the family on prone positioning of the patient while the casts are in place to maintain/increase the extension range.
- Obtain an anteroposterior radiograph 3 weeks postoperatively. If there is sufficient healing of the osteotomy sites, allow the patient to begin standing while wearing the casts.
- Remove the casts at 6 weeks, deliver the braces, and if radiographs show full healing, allow the patient to begin weight-bearing in physical therapy.

Fig. 8

Fig. 8 Postoperative Petrie cast. Bilateral long leg casts are applied with the knees as extended as possible and the foot positions corrected. The casts are then joined together by lashing, with plaster, an anterior and a posterior bar to the long leg casts, at the level of the ankles. If radiographs show sufficient healing at 3 weeks, standing therapy is started.

Step 9: Plate Removal

Remove the blade plate on an outpatient basis 12 to 18 months after the osteotomy, through the smallest incision possible to allow a quicker recovery.

- Remove the blade plate approximately 12 to 18 months postoperatively to prevent excessive bone overgrowth. If the plate is not removed from younger children, bone growth and remodeling will bring the blade of the implant inferiorly, penetrating the calcar. This can create a risk of fracture, and the plate may impinge on structures medial to the proximal part of the femur.
- To remove the plate, make an incision that is $\leq 50\%$ the length of the initial incision.
- Do not visualize the plate and screws directly; instead, rely on fluoroscopy to localize the screw heads. Clear each screw head of soft tissue by inserting the tip of a small hemostat into the head and rotating the hemostat tip vigorously.
- Insert the screwdriver into the screw head under fluoroscopic guidance, and repeatedly tap the screwdriver with a mallet until there is a sensation that the screwdriver is well aligned and therefore well seated in (“locked in”) the screw head. This is vital to avoid a misaligned screwdriver leading to a stripped screw head.
- Back out the screw a few turns; then advance the holding sleeve on the screwdriver to catch the screw head, making extraction of the screw easier.
- Once the screws have been removed, use a scalpel to incise the soft tissue longitudinally over the plate, as this tissue will often restrain the plate from being removed.
- Attach the plate inserter to the plate, and use the slide hammer to disimpact the plate from bone. Driving an osteotome between the plate and bone may help to elevate the plate off the bone.
- Remove the plate by delivering one of its ends through the incision.

Results

We performed reorientational osteotomies on 68 consecutive children with arthrogrypotic multiplanar hip contractures over a 5-year span, and 65 were followed for at least 2 years; 54 of these patients had a bilateral hip contracture, for a total of 119 reorientational osteotomies. The average age at the time of the procedure was 48 months (range, 13 months to 12 years and 10 months). The blade plate was explanted at a mean (and standard deviation) of 18 ± 8 months. The minimum follow-up time after the index procedure was 24 months, and the average was 40 months. Nearly 70% of the patients had the characteristic combination of hip flexion, abduction, and external rotation contractures. Eighty-one hips had a flexion contracture of $>20^\circ$ (mean, $-52^\circ \pm 19^\circ$; range, -95° to -25°); this improved by a mean of 34° , to $-18^\circ \pm 14^\circ$ (range, -55° to 0°), at the time of final follow-up ($p < 0.0001$). Eighty-four hips had $<15^\circ$ of adduction preoperatively (mean, $-20^\circ \pm 24^\circ$; range, -90° to 10°); this improved by a mean of 37° , to $19^\circ \pm 13^\circ$ (range, -20° to 35°), at the time of follow-up ($p < 0.0001$). One hundred and one hips with $<30^\circ$ of internal rotation in extension had a mean improvement of 39° , from $-16^\circ \pm 21^\circ$ (range, -75° to 25°) preoperatively to $20^\circ \pm 23^\circ$ (range, -15° to 85°) at the time of follow-up ($p < 0.0001$). Similarly, 101 hips had $<30^\circ$ of internal rotation in flexion, which improved by a mean of 36° ($p < 0.0001$). Of the 94 hips that had $\geq 90^\circ$ of flexion preoperatively, only 11 (in 9 patients) did not flex to 90° postoperatively. These 11 hips had a mean postoperative range of flexion of 79° (range, 65° to 85°), representing a mean loss of 32° . At the time of the latest follow-up, none of those patients had reported seating difficulties, and all but one walked independently. The other types of contractures treated included a lack of frog-leg abduction (21 hips) and a lack of regular abduction (10 hips); these showed no change from the preoperative visit to either the postoperative or latest follow-up evaluation. Also, 25 hips had $<90^\circ$ flexion, which improved by a mean of 12° , from $63^\circ \pm 17^\circ$ to $75^\circ \pm 21^\circ$ ($p = 0.018$) postoperatively, but the improvement was often not enough to be clinically relevant in terms of improving seating.

Preoperatively, only 6 patients (with a mean age of 7 years and 1 month) were ambulatory. At the time of the latest follow-up, 36 of the 65 patients were independent ambulators, most with braces (ankle-foot orthoses or knee-ankle-foot orthoses) and another 20 were walker-dependent. Nine patients were non-ambulatory, of whom 2 had had the procedure performed specifically to improve seating (Figs. 9-A through 10-D).

Fig. 9-A

Fig. 9-B

Fig. 10-A

Fig. 10-B

Fig. 10-C

Fig. 10-D

Figs. 9-A and 9-B A girl with characteristic arthrogryptic hip contractures of flexion, abduction, and external rotation. (Reproduced from: van Bosse HJ, Saldana RE. Reorientational proximal femoral osteotomies for arthrogryptic hip contractures. *J Bone Joint Surg Am.* 2017 Jan 4;99[1]:55-64.)

Fig. 9-A The image on the left shows the patient preoperatively, at 5.5 years of age, with the hips in their usual resting position. This patient's hip positioning was used in creating the bone model used in this article. The right image shows the same girl 2.5 years after the hip reorientational osteotomies and subsequent correction of knee flexion contractures with posterior knee releases and external fixation knee distraction. At the time of the latest follow-up—4 years after the reorientational osteotomy, when she was 10 years of age—the patient was walking wearing floor reaction ankle-foot orthoses.

Fig. 9-B Anteroposterior pelvic radiographs made preoperatively at 5.5 years of age (left image), at 2 months after the reorientational osteotomies (middle image), and at 10 years of age (right image).

Figs. 10-A through 10-D A girl with severe hip flexion and abduction contractures (same patient as shown in Fig. 1) who underwent bilateral percutaneous anterior hip releases and reorientational osteotomies at 16 months of age. **Fig. 10-A** The patient's usual hip positioning at rest before the operation, at the age of 16 months. **Fig. 10-B** The maximum hip flexion and extension preoperatively (see also Fig. 1).

Fig. 10-C Radiographs made preoperatively at 8 months of age (left image), immediately after bilateral reorientational osteotomy of the proximal part of the femora at 16 months of age (middle image), and 4 years postoperatively (right image). The plates were removed at 12 months after the osteotomies. Note the dramatic remodeling of the proximal parts of the femora; the greater trochanters were initially directly posterior after the osteotomies.

Fig. 10-D The patient at 3.5 years of age, at which time she was able to walk independently.

Pitfalls & Challenges

- Improving limited preoperative hip flexion is difficult. Although the 25 patients with $<90^\circ$ of preoperative hip flexion (mean, $63^\circ \pm 17^\circ$) in our study¹ had a mean improvement of 12° , to a mean of $75^\circ \pm 21^\circ$ at the time of follow-up ($p = 0.018$), this change often was not enough to be clinically important in terms of improved seating. However, the correction of associated contractures (for example, abduction and rotational contractures) through the reorientation led to meaningful improvement in the overall lower limb positioning of those patients, allowing improved seating. In older patients (12 years and older) who can comply well with physical therapy, a “posterior hip release” can be performed to address the limited hip flexion. Essentially, using the same lateral incision used for the osteotomy, the surgeon should elevate the muscle attachments sharply off the proximal extent of the linea aspera as a sleeve, leaving them attached distally to the periosteum and fascia. This will include the gluteus maximus and the adductor magnus and brevis. The fascia on the undersurface of the muscles can be carefully transected, allowing the muscles to stretch, until 90° of flexion is attained in the operating room. A strict regimen of physical therapy for hip flexion stretching is required for at least 2 to 3 months, since the results obtained in the operating room can be lost if sufficient stretching is not performed.
- The blade of the hip plate pulled out of the proximal fragment in 1 patient in our study¹. To prevent this from happening:
 - Use a metaphyseal screw in the proximal fragment when possible.
 - When applying the Petrie casts, place pressure on the lateral aspects of the upper thighs while the attachment of the long leg casts to the bar is hardening; this will serve to drive the blade deeper into the bone.
 - Do not allow caretakers to lift the patient in such a way that the cast dangles; whenever the patient is lifted, the cast should be supported so that there is no stress across the hips.
- In patients with 70° to 90° flexion contractures, consider the proximal osteotomy cut as defining the anterior wall of the new proximal part of the femur. What was the posterior metaphysis will now become the docking site for the distal fragment. Therefore, the proximal osteotomy is made parallel to the anterior surface of the seating chisel, rather than parallel to the blade of the chisel. Then, the posterior femoral metaphyseal cortex is planed with the sagittal saw, creating a flat surface parallel to the seating chisel blade. The distal fragment is shortened just enough to allow it to be apposed to the developed surface of the proximal fragment; then the 2 fragments are secured to the blade plate as described above (Figs. 11-A through 11-D).

Fig. 11-A

Fig. 11-B

Fig. 11-C

Fig. 11-D

Figs. 11-A through 11-D Sawbones (Pacific Research Laboratories) model of a 90° hip flexion contracture. **Fig. 11-A** The thick solid black line represents the opening for the blade-plate track, which is perpendicular to the coronal plane of the pelvis. **Fig. 11-B** The red line indicates the intertrochanteric osteotomy level, whereas the blue line indicates the region of the resection of the posterior aspect of the proximal femoral metaphysis, needed to create a docking site for the femoral shaft.

Fig. 11-C After removal of the posterior part of the proximal femoral metaphysis, which left a flattened surface. **Fig. 11-D** After intertrochanteric osteotomy, with the shaft lined up with the proximal fragment. The severe hip flexion contracture has been corrected.

- Fractures at the level of the implant have occurred within 2 months after implant removal. Radiographs should be carefully assessed immediately after explantation, and weight-bearing should be curtailed whenever the bone stock seems insufficient.

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Harold Jacob Pieter van Bosse, MD¹

¹Shriners Hospital for Children, Philadelphia, Pennsylvania

E-mail address for H.J.P. van Bosse: HvanBosse@Shrinenet.org

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