Technical Note

Three-Dimensional Navigation (O-arm) for Minimally Invasive Shelf Acetabuloplasty

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Abstract: Hip dysplasia is an important cause of osteoarthritis in young adults. For these patients, conservative treatment is an interesting alternative to arthroplasty. The current literature suggests better clinical and functional outcomes when shelf acetabuloplasty is performed for a moderate joint pinch (<50%) associated with an important external coverage defect of the acetabular cup (<25°). Compared with open surgical procedures, minimally invasive surgical techniques or arthroscopy tend to reduce morbidity. To date, the major intraoperative difficulty remains the positioning of the graft. This Technical Note aims to outline a minimally invasive shelf acetabuloplasty, with optimization of the position of the autologous iliac crest bone graft using 3-dimensional navigation.

Hip dysplasia is an important cause of osteoarthritis in young adults. For those patients, conservative treatment is an interesting alternative to arthroplasty. The current literature suggests better clinical and functional outcomes when shelf acetabuloplasty is performed for a moderate joint pinch (<50%) associated with an important external coverage defect of the acetabular cup (<25°, Fig 1).[1,2] Compared with open surgical procedures, minimally invasive surgical techniques or arthroscopy tend to reduce morbidity. This Technical Note aims to outline a minimally invasive shelf acetabuloplasty, inspired by that described by Chiron et al.,[3] with optimization of the position of the autologous iliac crest bone graft using 3-dimensional navigation.

Surgical Technique (With Video Illustration)

Patient Setup

The patient is placed in the supine position on a regular table. Legs should hang down at the end of the table, allowing mobilization of the O-arm (Medtronic, North Haven, CT) device while leaving space for the operating area (Fig 2). A positioner is put under the patient's thighs to avoid any pressure point and to keep the hip in a neutral position. A simple distal translation of the O-arm allows initial and final 3-dimensional radiographic shots.

First Step: Preparation of the Bone-Graft (Tricortical Iliac Crest)

The graft is a tri-cortical cuboid bone autologous graft taken from the anterior iliac crest (Video 1). A guidewire is inserted in the middle of the superior crest area, in the axis perpendicular to its lower edge. The transplant is then performed before his osteotomy. The graft should be 3 cm by 1.5 cm deep (Fig 3). While extracting the graft, the inferior part of the cuboid bone is beveled at 45° from top to bottom, and from lateral to medial. It optimizes the contact surface between the graft and the targeted periacetabular surface. Due to its concavity, the inferior part of the

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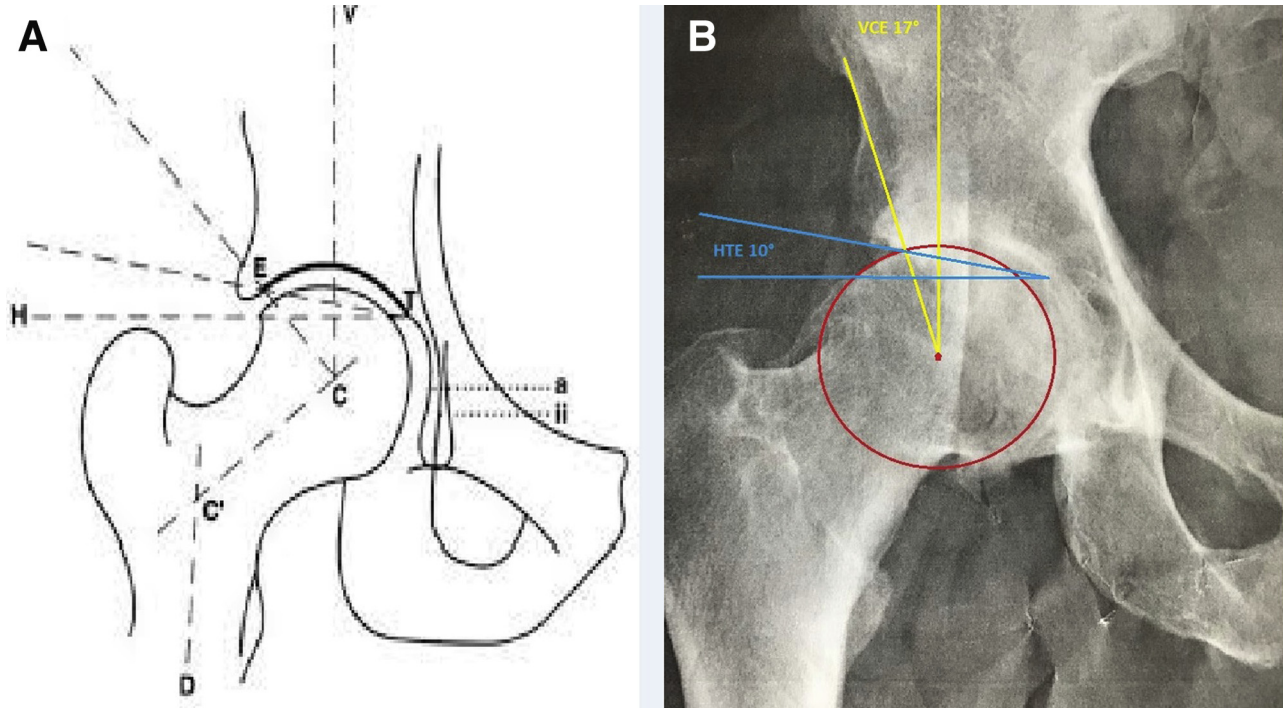

Fig 1. Schematization (A) and radiograph of a right hip (B) before shelf acetabuloplasty that shows a moderate joint pinch (<50%) associated with a moderate external coverage defect of the acetabular cup (External coverage angle VCE = 17°).

bone block is the medial cortex of the iliac crest, in contact with the joint capsule.

A 5-mm diameter cannulated sponge screw, with short threads and topped with a washer, is screwed on the graft to ensure compression on the iliac crest. Key steps are summarized in Table 1.

Second Step: Minimally Invasive Approach and Fixation of the Bone-Graft Under 3-Dimensional Control (O-arm)

A 3-cm incision is performed to insert the iliac graft. The incision is made in the middle of a vertical line going through the greater trochanter, narrowed on the front by a horizontal line which passes through the anterior superior iliac spine and in the back by a horizontal line passing through the greater trochanter (Fig 4).

The superficial fascia is open and the fibers of the tensor fascia lata muscle are dissected. Under 3-dimensional navigation, the guide wire is inserted up to the external iliac cortex and will optimize the positioning of the penetration point of the guidewire. Criteria used for the positioning of the graft are an anterolateral positioning 5 mm above the joint space combined with a 45° angulation. One Hohmann spacer should be slid in front of the wire under the anterior superior iliac spine, and another slid back on the upper part of the acetabular roof. The electric scalpel is used to cut through the reflected tendon of the anterior rectus muscle and to access the target

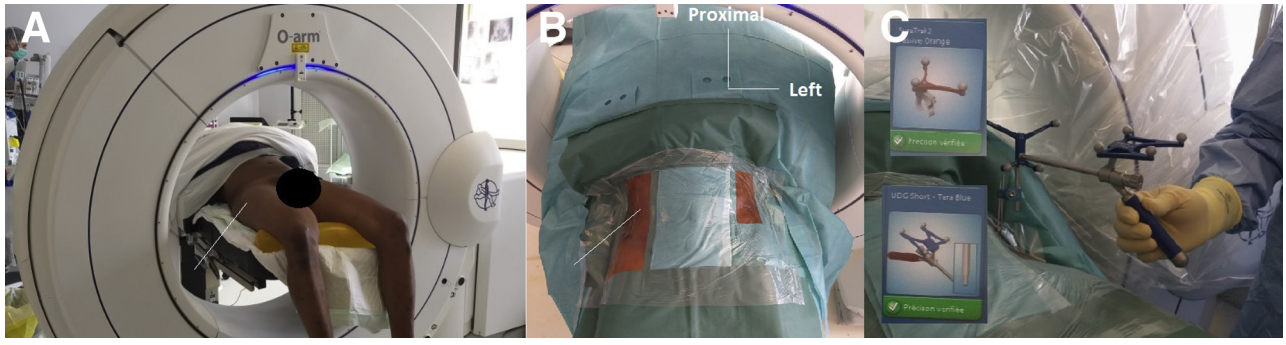

Fig 2. Patient is positioned in the supine position, legs hanging at the end of table (A). Setting up of the 3-dimensional navigation system (trackers on the contralateral iliac crest and on the cannular drill guide) (B-C).

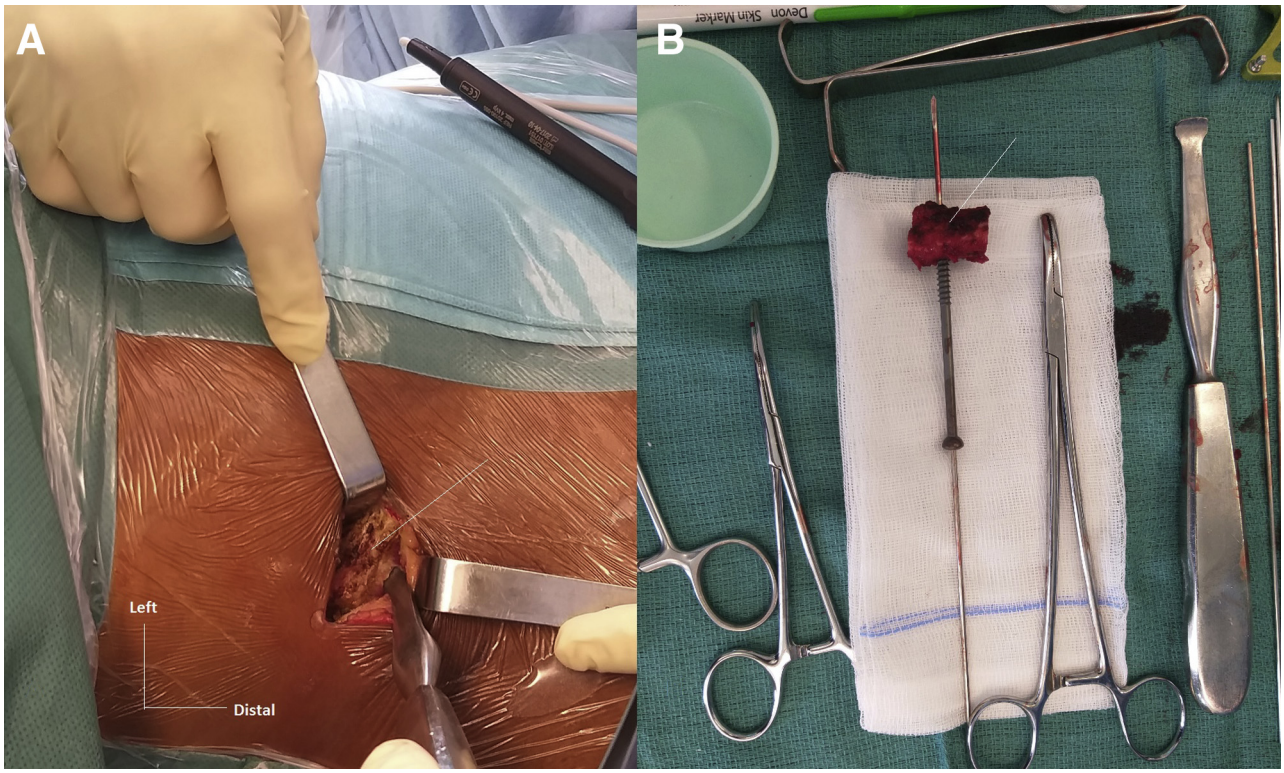

Fig 3. Triple cortical cuboid graft taken from the anterior iliac crest (A). After the graft osteotomy, a cannulated screw is screwed to prepare the graft and will ensure compression on the external periacetabular iliac wing (B).

periacetabular surface. The external cortex is sharpened using an aggressive curette or motorized burr. After bicortical drilling of the iliac wing, the graft with the cannulated screw is pushed along the guidewire (Fig 5). A forceps with teeth is used to direct and maintain the graft in the correct position during the screwing process (Fig 6).

Table 1. Key Steps for 3D Navigation for Minimally Invasive Shelf Acetabuloplasty

Patient Positioned in Supine Position, legs Hanging at the end of Table
Setting up of the 3D navigation system (trackers and cannular drill guide)
First step: Preparation of the iliac bone crest autograft
A 3-cm incision is made in front of the anterior iliac crest
Insertion of a guidewire in the middle of the crest grip area
Drilling before osteotomy the crest to facilitate positioning of the cannulated screw
Osteotomy of the iliac bone crest (3 cm long by 1.5 cm deep)
Second step: Minimally invasive shelf acetabuloplasty
A 3-cm vertical incision is made in the middle of the line going through the greater trochanter, in front of the axis passing by the anterior superior iliac spine
Opening of the superficial femoral fascia and dissection of the fascia lata muscle
Positioning of the guide spine under 3D navigation and drilling
Sharpening of the external cortex with a motorized burr
Introduction and screwing of the graft with a forceps with teeth

3D, 3-dimensional.

Rehabilitation Protocol

Initially, we recommend a non–weight-bearing ambulation for 8 weeks. However, from the outset,

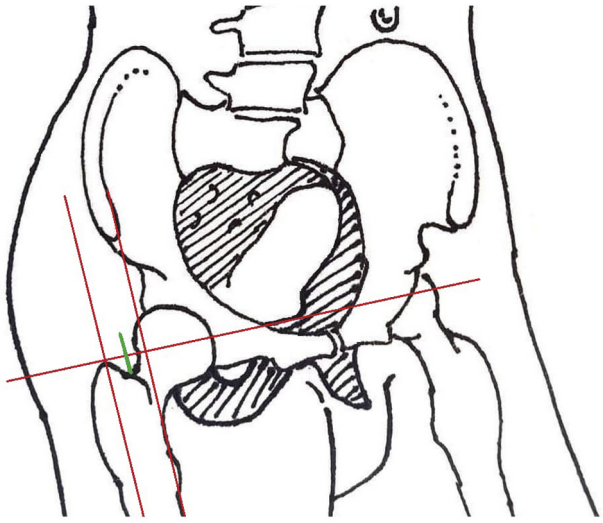

Fig 4. A 3-cm incision (green line) is made in the middle of a vertical line going through the greater trochanter, narrowed on the front by a horizontal line, which passes through the anterior superior iliac spine and in the back by a horizontal line passing through the greater trochanter (red lines).

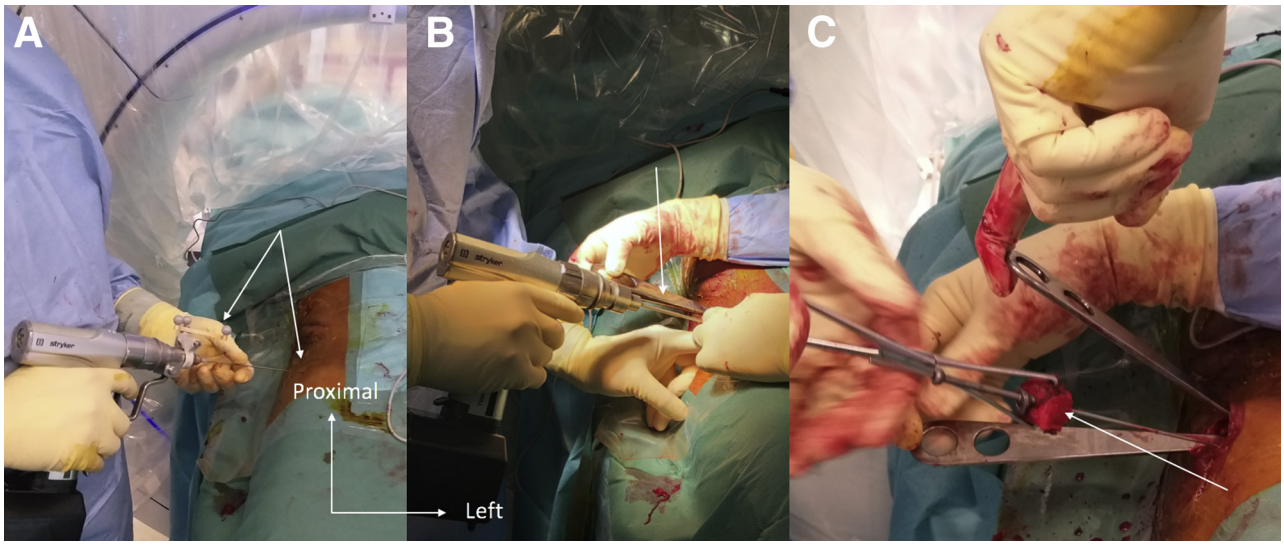

Fig 5. Under 3-dimensional navigation, the guidewire (double arrows) is inserted up to the external iliac cortex (A). The external cortex is drilled (arrow) and sharpened using an aggressive curette or motorized burr (B). After bicortical drilling of the iliac wing, the graft with the cannulated screw is pushed along the guidewire (C).

passive mobility is maintained with a threshold limit of 90° for hip flexion and 45° for hip abduction. A computed tomography scan is performed at day 60 to ensure the bone graft incorporation of the shelf acetabuloplasty and allow full weight-bearing.

Discussion

In the literature, shelf acetabuloplasty seems to be a reliable, safe procedure offering medium-term symptomatic relief for adults with acetabular dysplasia.[2,4-7] The major benefit of slotted acetabular augmentation is to alleviate hip pain by increasing load-bearing area. For Su et al.,[8] this benefit was not sensitive to preoperative radiographic parameters. In a multivariate analysis, Fujii et al.[9] indicated subchondral bone exposure on the femoral head as an independent risk factor for progression of osteoarthritis. However, best results are generally observed in case of mild or moderate dysplasia with beginning osteoarthritis.[2,7]

The acetabular shelves were positioned relatively more anteriorly than posteriorly. This appears to be appropriate owing to the relative anterior deficiencies of the acetabuli in patients with hip dysplasia.[2] In our experience, 3-dimensional navigation has made it possible to optimize the anteroposterior and supra-acetabular positioning of the bone graft.

We use an iliac wing bone autograft to avoid potential immune incompatibility and graft reabsorption. Grafts were taken by removing the inner table of the ilium from 2 cm posterior to the anterior superior iliac spine, which resulted in minimal morbidity and neither pain or functional limitations.[10] The minimally invasive

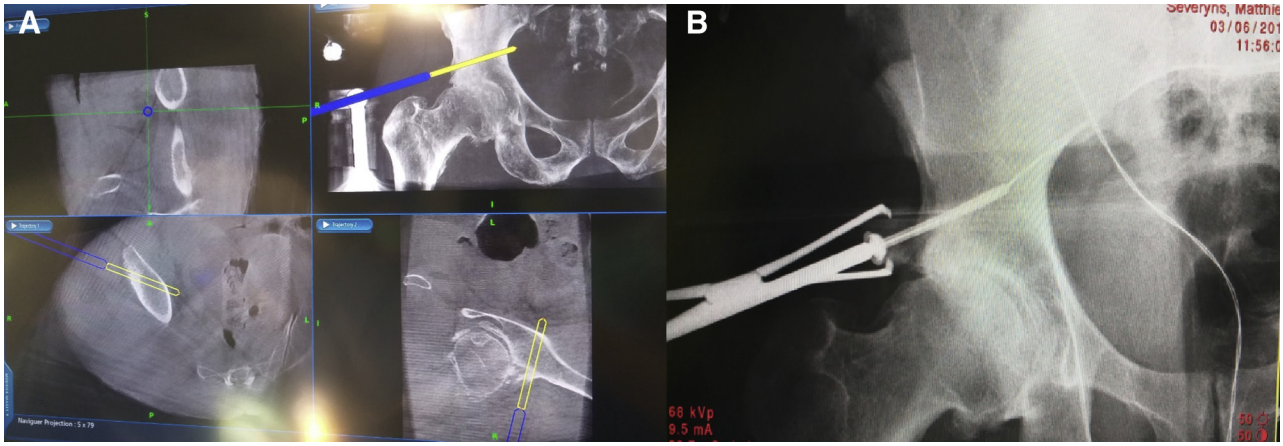

Fig 6. Three-dimensional navigation (O-arm) to optimize the shelf acetabuloplasty 5 mm anterolateral from the joint space combined with a 45° anteroinferior angulation (A). Intraoperative radiograph control that allows one to appreciate the graft compression (B).

Table 2. Pearls and Pitfalls

Pearls	Pitfalls
Start with the shelf drilling before its osteotomy	Stay away from the cutaneous femoral nerve (projection line of the anterior superior iliac spine)
Optimization of the contact surface with a shelf beveled at 45° from top to bottom	Reduction difficulty due to reflection tendon of the anterior rectus muscle (section)
Sharpening of the external iliac cortex with an aggressive curette or motorized burr	Learning curve of the use of three-dimensional navigation
Use a forceps with teeth during the screwing process	

surgical approach at the anterolateral part of the hip permits the securing of the cutaneous femoral nerve.[3] From our experience, the projection line of the anterior superior iliac spine seems to be a reliable landmark to minimize neurologic damage. The main long-term complication remains the autologous graft nonunion. Two elements are important to consider. Preparation of the external iliac cortical could be difficult and the cause of nonunion; therefore, it may be necessary to drill with a motorized cutter under fluoroscopic control. Secondly, to permit a good graft positioning without soft-tissue interposition, section of the reflected tendon of the anterior rectus muscle is needed. Pearls and pitfalls are summarized in Table 2.

Minimally invasive shelf acetabuloplasty under 3-dimensional navigation is a reliable and secure technique. Unquestionably, the surgeon's familiarization with the navigation device makes this procedure fast and easily reproductible. The learning curve for the use of navigation is not negligible. Despite this, shelf acetabuloplasty under the O-arm seems to be shorter than open or endoscopic procedures.

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