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SYMPOSIUM: DEVELOPMENTAL DYSPLASIA OF THE HIP

Endoscopy-assisted Periacetabular Osteotomy

A Preliminary Cadaveric Study

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Abstract Periacetabular osteotomy has been recommended for reconstructing symptomatic dysplastic hips in adolescents and young adults, but requires substantial incisions and exposure. To minimize large incisions, we asked whether periacetabular osteotomy could be performed with a mini-incision under direct endoscopic control. We used five fresh-frozen cadaver pelves and developed curved guides and osteotomes for the osteotomy. We were able to perform a periacetabular osteotomy under endoscopic and image intensifier control and to fix the osteotomy with two cannulated screws. We identified no damage to vital structures or intraarticular fracture in any of the five cadavers we subsequently dissected. We believe periacetabular osteotomy may be performed with a mini-incision under direct endoscopic control. Our preliminary observations suggest the approach might be explored in limited prospective clinical trials by experienced individuals.

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Each author certifies that his or her institution has approved the human protocol for this investigation and that all investigations were conducted in conformity with ethical principles of research, and that informed consent for participation in the study was obtained.

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Introduction

Periacetabular osteotomy (PAO) was described for reconstructing symptomatic dysplastic hips in adolescents and young adults [4, 10, 12, 17–20]. This procedure consists of an extensive exposure and careful cutting of the pelvic bones (ischium, pubis, ilium) around the acetabulum, to free it from its original position [4]. However, the maintenance of an intact posterior column preserves the intrinsic stability of the pelvis. PAO is considered a technically difficult operation, and various reports suggest most of the complications consist of major neurovascular injuries or intraarticular fractures occurring at the beginning of the learning curve [1, 3, 7, 15, 21].

To minimize complications, several modifications have been used. Ninomiya and Tagawa [14] used a specially designed osteotome and an approach that combines the anterior iliofemoral and posterior approaches through a single skin incision. Ko et al. [10] advocated a modified Ollier approach, which allows osseous cuts to be made under direct vision and is easily learned. Despite these improvements, performing PAO requires major surgical exposure with a complication rate comparative to those reported earlier [4, 17].

To reduce surgical trauma, blood loss, and incision scar, arthroscopy-assisted minimal invasive surgical techniques have been recently developed for orthopaedic surgery [22, 23]. Wall et al. [22] described an endoscopically assisted triple innominate osteotomy technique. Potential advantages included direct visualization of the bone cut, minimal surgical dissection, and rapid postoperative recovery. Another study advocated PAO using computer-assisted navigation; the authors concluded computer-assisted navigation improved the accuracy and safety of the complex orthopaedic procedure [6].

With the same aim, we asked whether PAO could be performed with a mini-incision under direct endoscopic control without damage to the acetabulum and key neurovascular structures.

Materials and Methods

We first reviewed patient medical records and selected 14 patients who had 3-D computed tomography (3-D CT) scans of the pelves, which were normal with no pathological findings. Wagner Type II spherical osteotomy [17] was simulated on the 3-D CT reconstructions (Brilliance CT 40-channel, Philips Medical Systems, Cleveland, OH). The osteotomy began above the acetabular rim 1 cm proximal to the anterior inferior spine and continued down to the obturator foramen parallel to the acetabular articular surface. With these simulations, we developed curve-shaped guides and osteotomes to approximately correspond to the circumferential curvature of the acetabulum (Fig. 1A). We made the curved guides, which we call "acetabulum finders", in three sizes and osteotomes with similar radii in three different lengths; these replicated three common radii found for the circumferential osteotomy line on the simulations (Fig. 1B). These guides were intended to follow a course between the inner and outer tables of the ilium. To avoid perforation of the acetabulum with an osteotome, we identified a safe zone using a computer reconstruction of the pelvis (Adams, MSC Software Corporation, Santa Ana, CA). The safe zone was the region beginning at the acetabular rim that avoided penetration into the acetabulum and the medial column of ilium (Fig. 2). As a preliminary test we used two cadavers (not included in the study) to ensure that our new instruments worked properly. In our preliminary cadavers, we used the same incision to perform the osteotomy and endoscopy but we were not always able to observe the osteotome while making the bone cut. Subsequently, we used a new endoscopic portal as described below.

We then obtained five fresh-frozen cadaver pelves to ascertain whether the approach was practical and safe. The five male donors were 22, 34, 38, 49, and 61 years of age at the time of death. We placed the cadavers supine with a roll under the hip on a radiolucent operating table. We performed a longitudinal 3-cm incision between the anterior-superior and inferior iliac spine (Fig. 3). The dissection was carried down to the ilium. The lateral and medial walls of the iliac wings were exposed subperiosteally by using a periosteal elevator. To determine the starting location of the osteotomy line, we inserted a short acetabular finder 1 cm proximal to the anterior-inferior iliac spine under an image intensifier (Fig. 4A–B). To identify the circumferential curvature of the acetabulum,

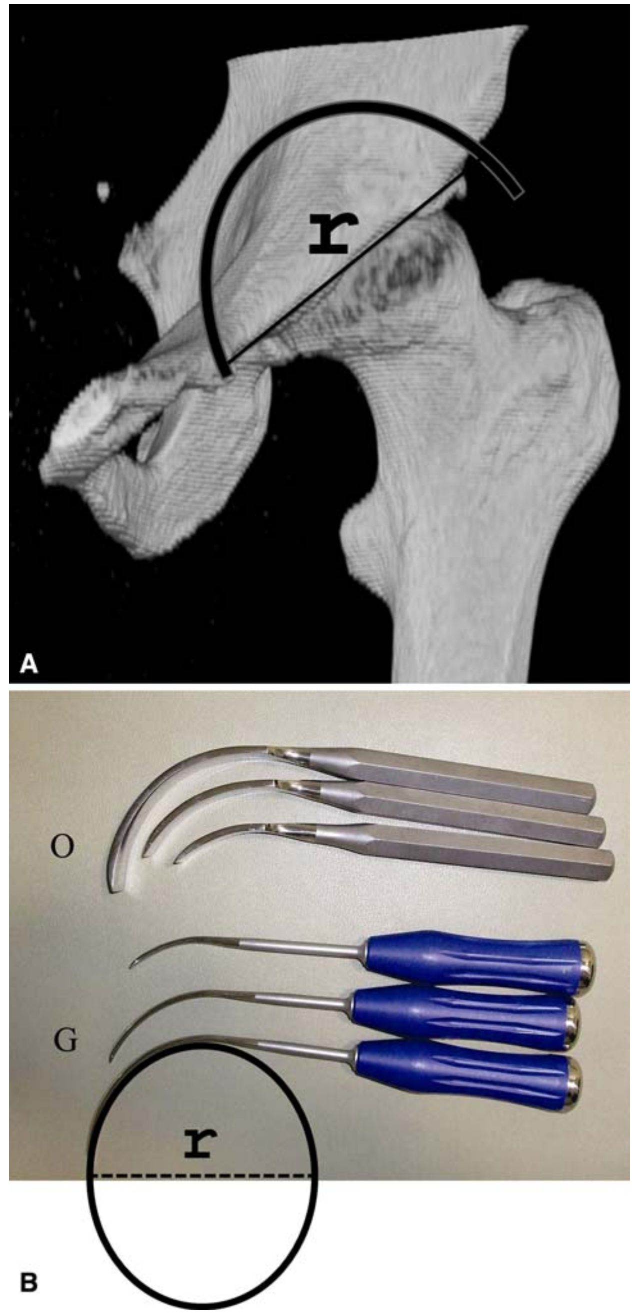


Fig. 1A–B (**A**) A radiograph shows the radius of the circumferential osteotomy line (r) on the simulation. (**B**) We show the three sizes of the guides (G) and osteotomes (O) developed to achieve circumferential periacetabular osteotomy.

the guide was replaced by a longer one and the tip of the guide advanced until it was at the posterior border of the ischium (Fig. 4C–D). We confirmed the proper size and placement of the guide with anteroposterior and lateral image-intensified radiographs. The proper size guide as observed on the image intensifier indicated which of the three osteotomes we would use.

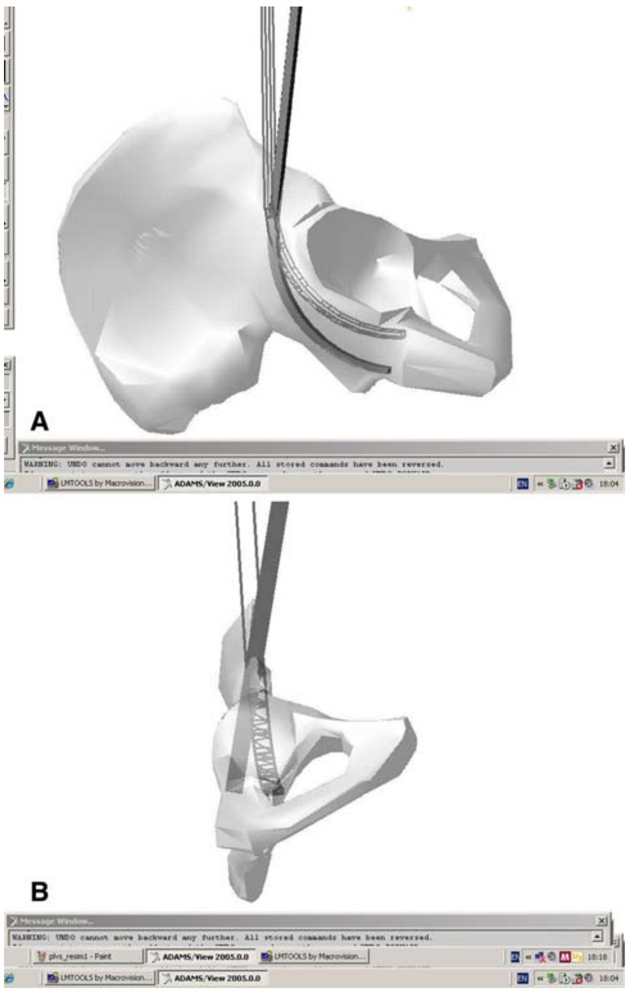


Fig. 2 The safe zone was identified using a computer model of the pelvis. The safe zone stayed within between the inner and outer walls of the ilium and avoided penetration of the osteotome into the acetabulum and the medial column of ilium in the coronal plane.

As noted earlier, we initially used the same incision to perform osteotomy and endoscopy; however, we were unable to observe the osteotome during osteotomy. We then used the portal described by Zobrist et al. [23] for endoscopy-assisted anterior pelvic ring stabilization using a similar exposure in order to visualize the ilium. The endoscopy portal was opened 8.5 cm distal to the umbilicus and 4 cm lateral to the midline to view the ilium (Fig. 5) and advance a trocar inferiorly while endoscopically viewing the epigastric vessels and transilluminating the abdominal walls. CO_2 gas was used to expand the extraperitoneal region. The endoscope was 10 mm in diameter with a 0° optic (Storz, Germany). The endoscope was directed laterally from the symphysis to the pubic rami, taking special care to identify and preserve anastomotic vascular structures (Fig. 6). The medial wall of the iliac wing was endoscopically exposed through a longitudinal split of the iliacus muscle.

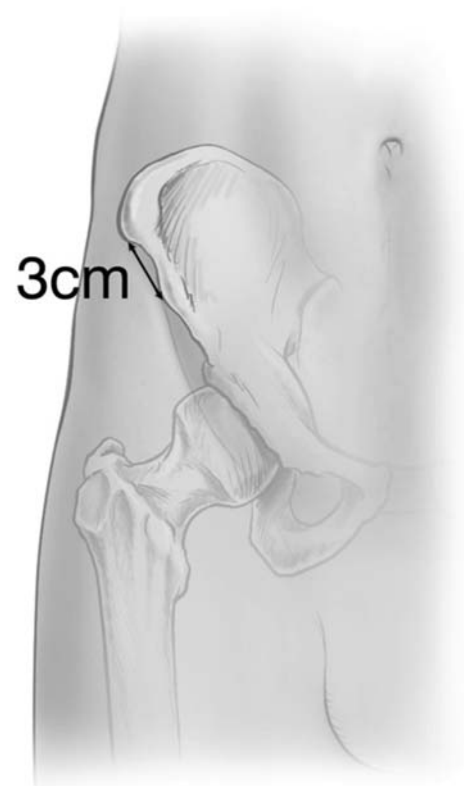


Fig. 3 We illustrate the longitudinal 3-cm incision was placed between the anterior superior and inferior iliac spine.

To perform PAO through the initial incision, we inserted a short, curved osteotome and visualized the osteotomy under endoscopic control (Fig. 7A–B) and the iliac vessels were visualized and preserved during this maneuver. We completed a curvilinear osteotomy of the medial wall using a longer osteotome (Fig. 7C–D). All steps were followed by an image intensifier and endoscopy. To complete PAO, the lateral wall of the ilium was then cut blindly by using a guide and osteotome (Fig. 8). The sound of the hammer permits detection of when the tip of the osteotome reaches the outer cortical bone.

Using the initial incision, we palpated the location where the superior pubic ramus met the acetabulum and directed a short, curved osteotome toward the superior pubic ramus. We placed a radiolucent malleable elevator into the obturator foramen to protect neurovascular structures. Osteotomy of the superior pubic ramus was performed with an osteotome 1 cm from the medial acetabular wall under endoscopic visualization (Fig. 9A–B). Bone mobility was controlled by twisting the osteotome in the osteotomy site.

We used a laminar spreader to spread the iliac wing osteotomy and to complete the most inferior part of the osteotomy by osteoclasis. A 4-mm Steinman pin was inserted just above to the anterior inferior iliac spine under

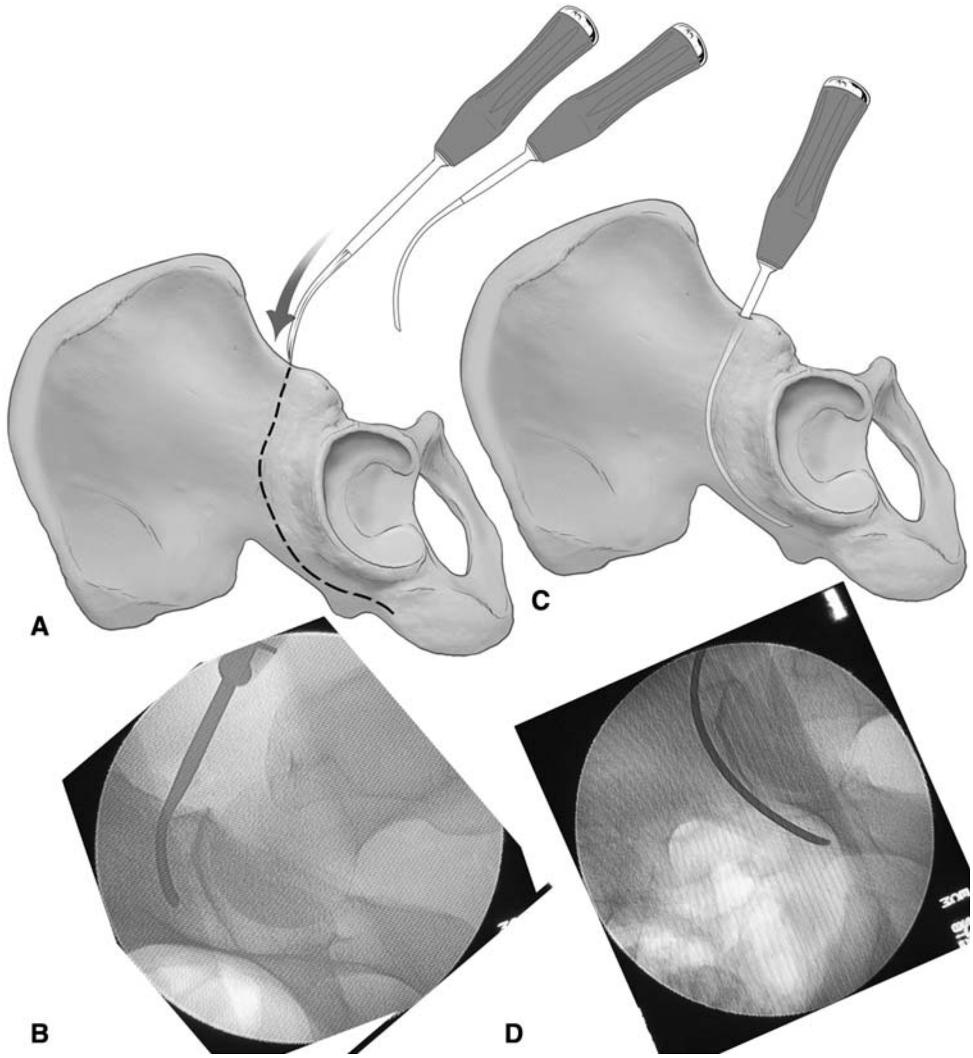


Fig. 4A–D (**A**) A drawing and (**B**) a radiograph show a short guide inserted 1 cm proximal to the anterior-inferior iliac spine. (**C**) The drawing demonstrates a shorter guide is replaced by a longer one and the tip of the guide was stopped immediately to ischial bone. (**D**) The image intensifier radiograph shows longer guide stopped immediately to ischial bone.

the image intensifier (Fig. 10A–B). We positioned the acetabulum in the desired position under image intensifier control using the Steinman pin as a joystick. The allograft was impacted into the open osteotomy site. We initially fixed the osteotomy with two threaded Kirschner wires from above the anterior inferior iliac spine to the iliac wing. We then used a 4.5-mm cannulated drill to prepare a screw hole over the wires and fixed the site with two cannulated screws (Fig. 11A–B).

We dissected the cadavers after the procedure was completed to visually check for neurovascular injuries related to the technique.

Results

To avoid perforation of the acetabulum with an osteotome, we first identified the safe zone on 3-D CT (Fig. 2). With the osteotomy beginning 1 cm proximal to the anterior inferior spine in supine position, the osteotomy could be kept within the safe zone if the direction of the osteotome did not exceed 26° in the coronal plane and 12° in the transverse plane.

We identified no visual damage to vital structures in any of the five dissected cadavers. PAO was achieved without intraarticular fracture.

Discussion

Open surgical technique and internal fixation of PAO is an accepted procedure in the treatment of acetabular dysplasia [2, 4, 5, 9, 12, 13]. Compared with the conventional open surgical technique, endoscopic techniques typically minimize the soft tissue damage caused by the surgical approach. We therefore asked whether PAO could be performed with a mini-incision under direct endoscopic control without damage to the acetabulum and key neurovascular structures.

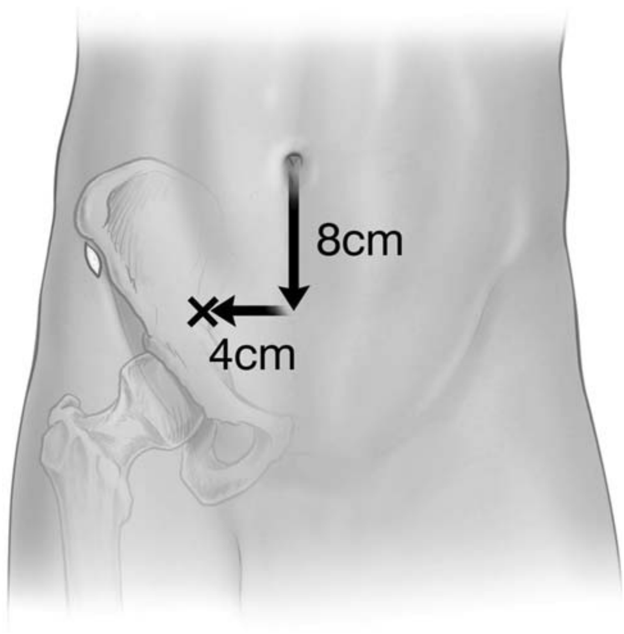
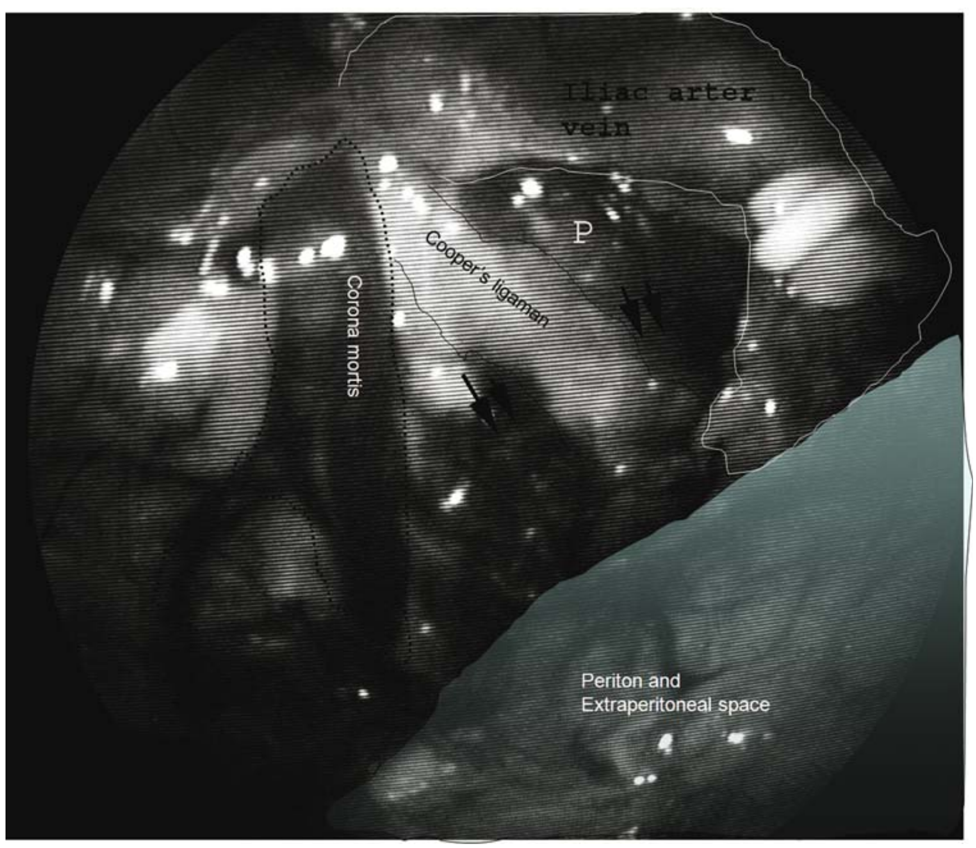


Fig. 5 The endoscopy portal is opened 8.5 cm distal to the umbilicus and 4 cm lateral to the midline.

The limitations of this study include performing a PAO on the small sample number. Surgeons should be aware of some modifications of the acetabular morphology in the dysplastic hip. We recognize the deformities of acetabular morphology in the dysplastic hip and our developed instruments may not be most appropriate for the dysplastic hip. However, most PAOs are performed on modestly deformed hips without subluxation or dislocation. Further, if necessary, the guides and osteotomes could be designed according to the preoperative analysis of the acetabulum from 3-D CT on dysplastic hips. The second limitation was we did not have to be concerned about bleeding in a cadaveric study. However, Wall et al. [22] demonstrated bleeding after superior pubic ramus osteotomy might block visualization. This concern might be partly addressed by adding to the number of cadaveric studies to demonstrate the reproducibility. Animal studies would not likely be of help because of the substantially distinct anatomy. Obviously, the ultimate safety in patients would need to be demonstrated in a preliminary study by surgeons fully skilled in the technique and prepared to manage bleeding.

After detailed anatomic studies, we developed an endoscopic-assisted PAO. Before the first clinical case we verified the feasibility of the approach with five cadaver experiments. With the assistance of the endoscope, our minimal approach allowed exposure and visualization of all essential structures without causing damage to soft tissues. It also facilitated the subsequent POA and stabilization of the osteotomy. However, the cutting of the

Fig. 6 The endoscopic view demonstrates the medial wall of the iliac wing. The osteotomy line is shown by arrows. P: Pubis.



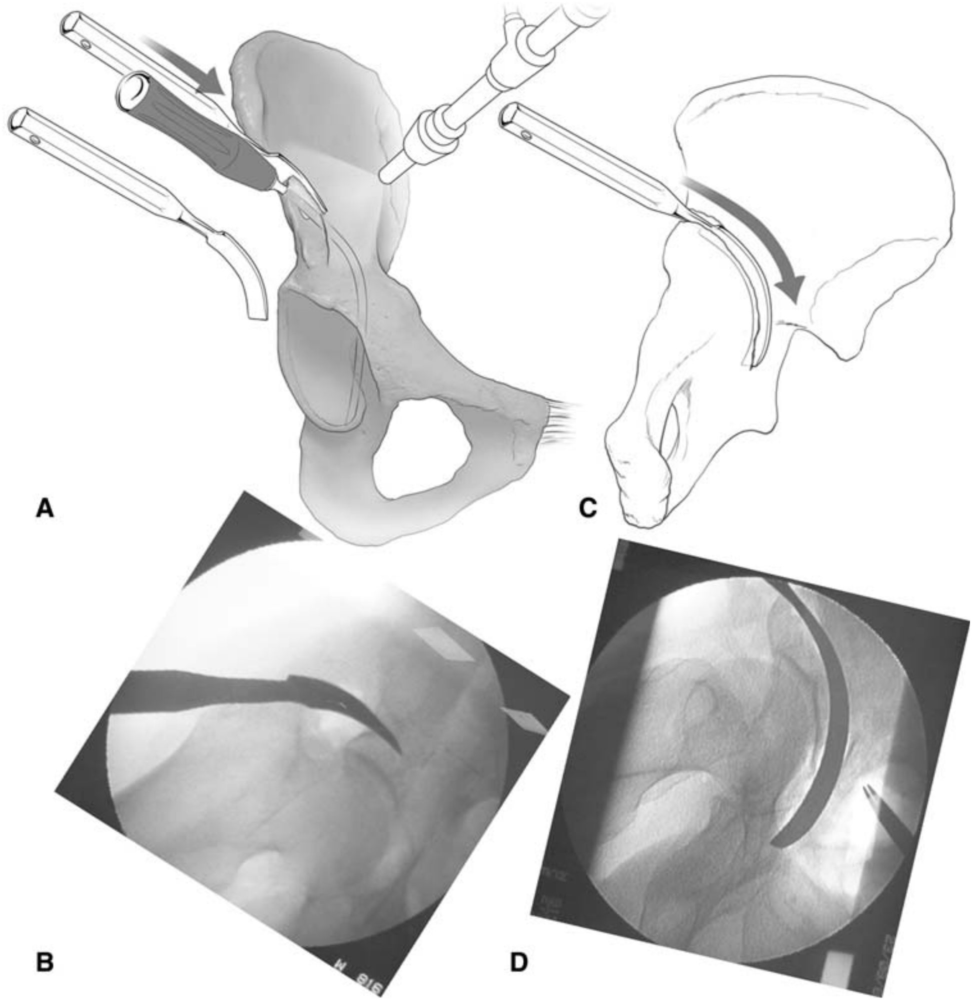


Fig. 7A–D (**A**) A short curved osteotome is demonstrated on the drawing to achieve a curvilinear osteotomy of the medial wall, and (**B**) an osteotome is shown on the image intensifier. (**C**) The drawing shows a longer osteotomy to complete inner iliac wall osteotomy. (**D**) The image intensifier shows a longer osteotome used inner iliac wall osteotomy.

superior pubic ramus has potential risk due to its close relation with neurovascular structures. Rubel et al. [16] showed endoscopy permitted access to the inner table of the ilium above the roof of the acetabulum. Zobrist et al. [23] performed the screw fixation of the superior pubic ramus alone under endoscopic control; they concluded the plate fixation for acetabular and pelvic fractures might be facilitated by using endoscopic technique. We found osteotomy of the superior pubic ramus may be achieved using a curved osteotome, and the neurovascular structures must be preserved by a malleable retractor. If the surgeon is concerned about potential damage, they could use a 3-cm vertical skin incision in the groin to perform open osteotomy of the superior pubic ramus [22].

There is a potential risk of intrapelvic vascular injury while a PAO is performed. To define the relation of these vascular structures to the bone around the acetabulum, Kambe et al. [8] measured the distance and direction from the anteroinferior iliac spine to the external iliac artery and from the base of the superior pubic ramus to the obturator artery. The distance to the external iliac artery was an average of 31.7 mm (range, 26–41 mm) in women and 38.2 mm (range, 27–53 mm) in men; and the distance to the intrapelvic entry portal of the obturator canal was 27.2 mm (range, 19–31 mm) in women and 33.4 mm

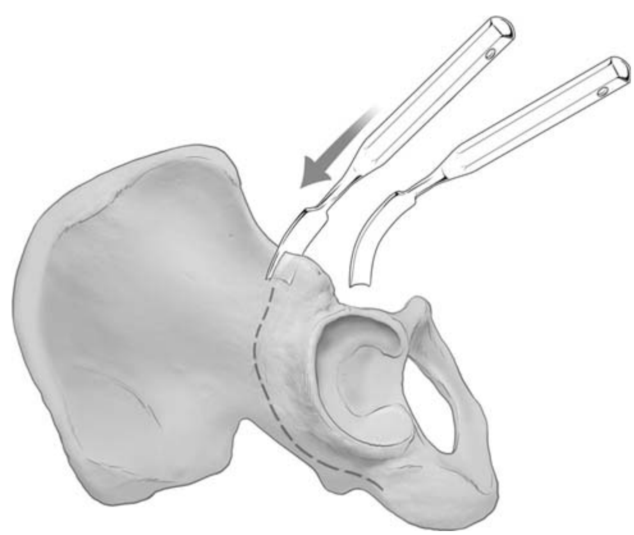


Fig. 8 The drawings show the osteotomy line on the lateral wall of the ilium.

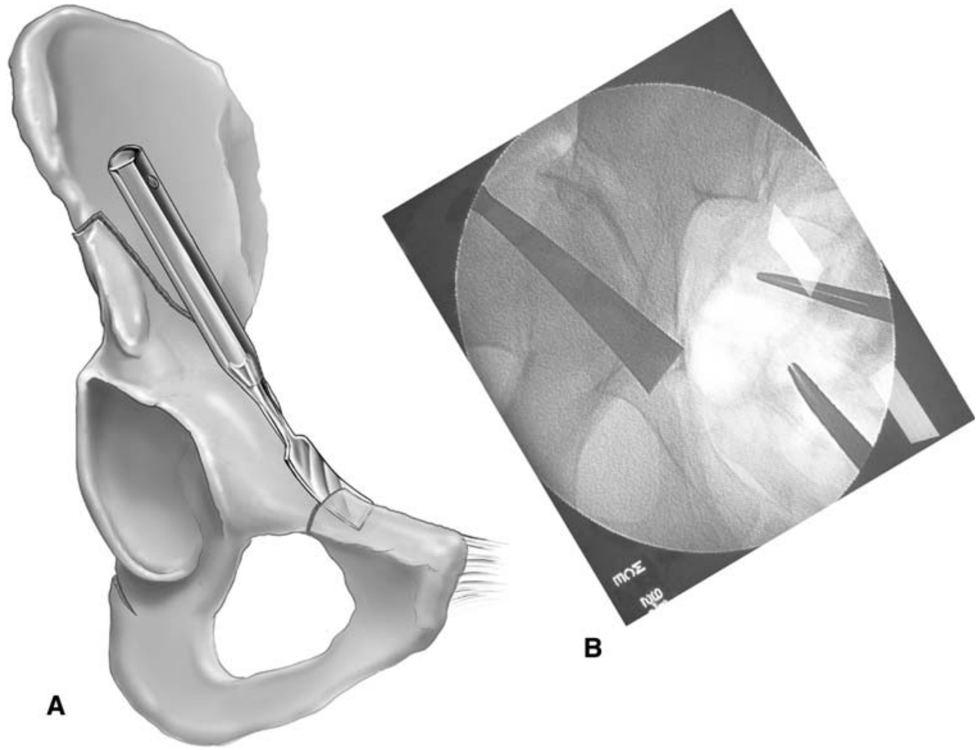


Fig. 9A–B (**A**) A drawing and (**B**) a radiograph show the osteotomy of the superior pubic ramus performed with an osteotome.

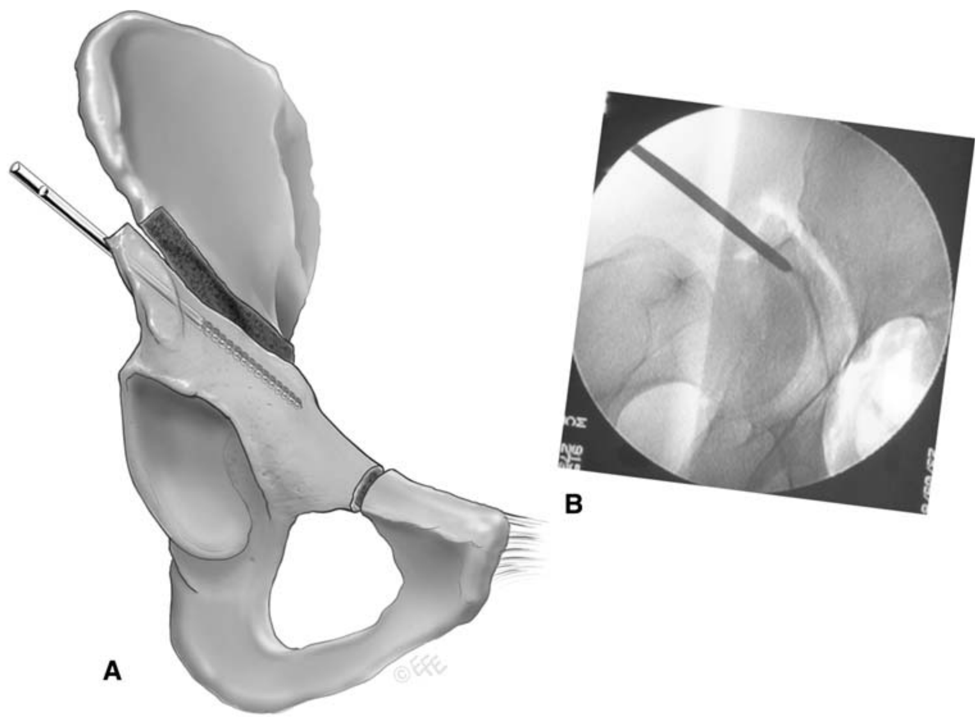


Fig. 10A–B (**A**) A drawing demonstrates a 4-mm Steinman pin inserted just above to the anterior inferior iliac spine. (**B**) The radiographic view shows a 4-mm Steinman pin used repositioning of the acetabulum.

(range, 26–40 mm) in men. Wall et al. [22] reported the obturator nerve and artery lie 4 to 8 mm posterior to the superior pubic ramus osteotomy and might be protected with a malleable retractor. Although the vascular structure lies in close proximity to the acetabulum, we found osteotomy could be performed safely under direct endoscopy visualization and image intensifier control. However, because our study describes endoscopic technique on a cadaveric model, clinical experience and followup is still necessary to clarify this question.

The issue of the learning curve is critical. Based on our initial experience, we believe the endoscopy-assisted PAO

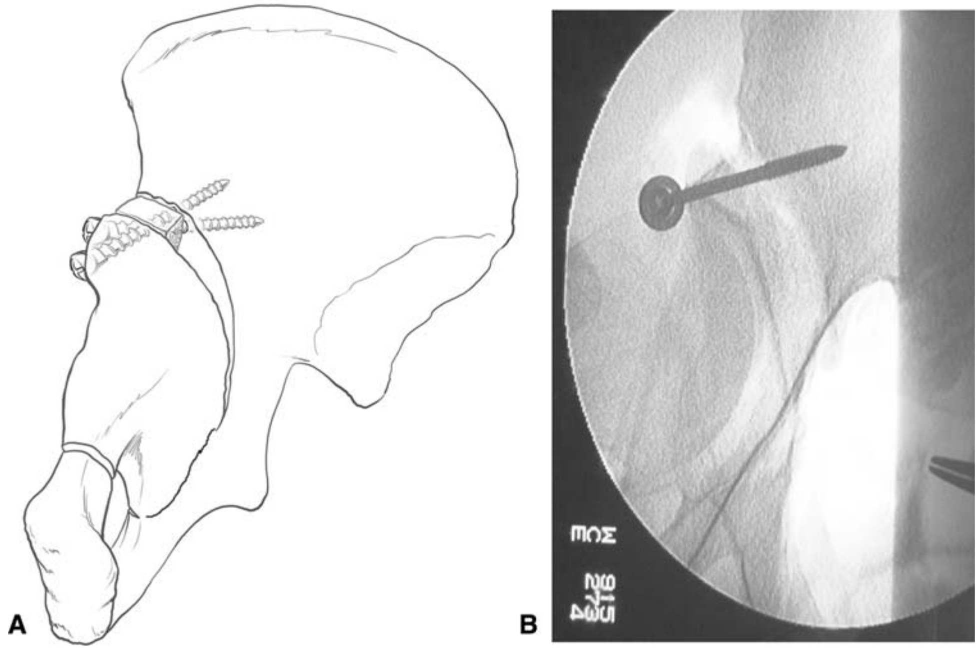


Fig. 11A–B The acetabulum is placed in the desired position and an allograft is impacted into the open osteotomy side. (**A**) Internal fixation provided by a 4.5-mm cannulated screw is observed on the picture. (**B**) The radiograph shows fixation of the acetabular osteotomy by using a 4.5-mm cannulated screw.

technique will not be easy to learn and complication rates might be high in the beginning. Even if we can confirm its utility in subsequent studies, we will undoubtedly recommend surgeons be quite familiar with open surgical techniques and perform cadaveric operations before trying the approach. Thereafter, endoscopy-assisted PAO may be useful for experienced surgeons.

The design of the osteotome is crucial to achieving curvilinear osteotomy. Ganz et al. [4] and Ninomiya and Tagawa [14] developed their osteotome for PAO. Later, Koyama et al. [11] developed a novel computer-assisted surgical tool with a curved blade that operates under the guidance of an optical navigation system and rotational acetabular osteotomies were performed on cadaveric pelves. We designed special curved osteotomes and guides. We believe guides (acetabular finders) are important added tools to safely perform PAO, and in the future these can be adapted to a computer system.

We have preliminarily demonstrated PAO may be performed with a mini-incision under direct endoscopic control and that the technique is a possibility for clinical application after further preclinical development.

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