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ORIGINAL ARTICLE

Extraarticular Fractures after Periacetabular Osteotomy

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Abstract Extraarticular fractures of the pelvic ring after periacetabular osteotomy could impair stability of the acetabular fragment and cause poor clinical and radiographic outcomes. We evaluated 17 patients (17 hips) with fractures of either the ipsilateral os pubis (n = 12) or os ischium (n = 5) during the postoperative period after periacetabular osteotomy. Ischial fractures seemed more debilitating with two of five resulting in painful nonunions for which additional surgery was performed. In contrast, only one patient with pubic fracture had additional surgery. Ischial fractures took almost twice as long to achieve resolution of symptoms compared with pubic fractures, and when left untreated, asymptomatic nonunions developed in three of five. However, we observed no effect on acetabular fragment positioning or long-term clinical outcome. It is essential to be aware of this potential complication and realize it could be accompanied by substantial morbidity for patients during the rehabilitation period after periacetabular osteotomy, but does not seem to influence the longer-term outcome.
Level of Evidence: Level IV, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

Study conducted at the Department of Orthopaedic Surgery, Children's Hospital, Boston, MA.
Each author certifies that he or she has no commercial associations (eg, consultancies, stock ownership, equity interest, patent/licensing arrangements, etc) that might pose a conflict of interest in connection with the submitted article.
Each author certifies that his or her institution has approved the human protocol for this investigation, that all investigations were conducted in conformity with ethical principles of research, and that informed consent was obtained.

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Introduction

Although the Bernese periacetabular osteotomy (PAO) is useful in treating dysplastic hips, it is technically demanding and complications frequently occur [3, 5, 7, 14, 16, 19, 23, 27]. The overall incidence of major complications is reportedly as much as 46% depending on the skill of the operating surgeon [5]. Numerous complications have been reported, including neurovascular injury, infection, hematoma, deep vein thrombosis, heterotopic ossification, nonunion, osteonecrosis, inadvertent fracture extension into the joint or into the sciatic notch, and need for additional surgery [4, 5, 8, 21, 28]. Additionally, intraoperative ischial fractures and either delayed union or nonunion of the pubis because of difficulties in fragment positioning and large corrections have been reported with a low incidence [7, 8, 26, 28]. We have observed, but not found, published reports of delayed fractures of the pelvis after PAO.

Among all complications, those that may cause substantial patient morbidity must be distinguished from those with little clinical importance or need for specific treatment. In patients with postoperative fractures of the pelvic ring who underwent PAO we suspected fracture location would be of major importance in making this distinction.

Stress fractures of the pelvis, when seen in young athletes, generally are treated nonoperatively with little morbidity [6, 17]. In young athletes, the stress fracture is isolated and does not destabilize the pelvis. However, extraarticular fractures after a PAO are not isolated events: the additional instability caused by the ipsilateral fractures of either the ischium or pubis after osteotomy could lead to delayed healing with prolonged pain and interference with postoperative recovery for patients. Some fractures might remain symptomatic and require additional surgical intervention. Furthermore, the fracture might destabilize the pelvis resulting in delayed healing of the osteotomy sites and loss of correction. The long-term consequences could be worse clinical outcome and progression of osteoarthritis.

We hypothesize the clinical presentation and interventions required for resolution will differ between pubic and ischial fractures. However, if properly treated, we hypothesize that equally good clinical outcome may be achieved despite these extraarticular fractures.

Materials and Methods

From a database, we retrospectively identified all patients who sustained a fracture of either the ipsilateral pubis or ischium within the first year after PAO; the database contained information on 526 PAOs performed in 425 patients between January 1994 and December 2003. All PAOs were performed according to the standardized method described by Ganz et al. [7]. Intraoperative radiographs were taken to confirm the absence of fracture before transferring the patient to the postanesthesia care unit. All patients were included who sustained an ipsilateral pubic or ischial fracture after they were discharged from the postanesthesia care unit. Extraarticular fractures were defined as discontinuities of the bone other than the osteotomies and that did not occur during surgery. We identified five patients (five hips) diagnosed with ipsilateral ischial fractures and 12 patients (12 hips) with ipsilateral pubis fractures that occurred within the first postoperative year after PAO (Fig. 1). None of the patients had additional comorbidities (eg, osteoporosis, malignancies) that could contribute to or increase the fracture risk, although one female patient had Down syndrome and another had Charcot-Marie-Tooth disease. The minimum age of these patients at the time of surgery was 13 years (mean, 27 years; range, 13–47 years). There were 15 females and two males with a minimum followup of 2 years (mean, 5 years; range, 2–11 years) at the latest clinical evaluation (Table 1). The minimum followup was 3 years (mean, 7 years; range, 3–9 years) for the ischium fracture group and 2 years (mean, 4.5 years; range 2–12 years) for the pubic fracture group. The interval from initial surgery until occurrence of a fracture of the ischium averaged 1.5 months (range, 0.25–2 months), and for pubic fractures it was 3 months (range, 0.25–10 months). The overall incidence of postoperative fractures was calculated as 3%. The incidence of ischium fractures was 0.9% and that of pubis fractures 2.1%. The Institutional Review Board of the hospital approved the study.

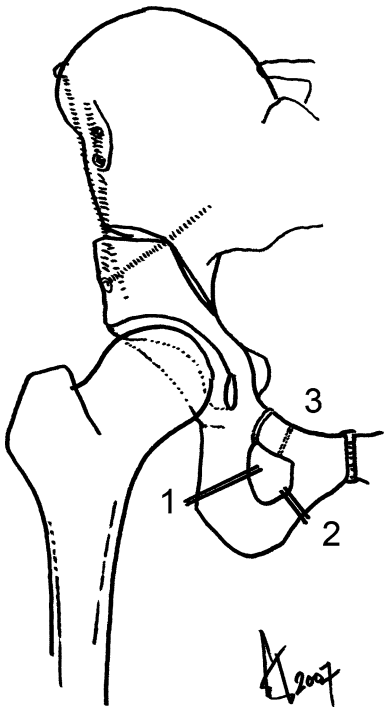

Fig. 1 The approximate locations of the (1) ischial, (2) inferior ramus, and (3) superior ramus fractures are shown.

Table 1. Demographics

Demographics and fracture history	Ischium	Pubis
Number	5	12
Female:male	4:1	11:1
Left:right	3:2	10:2
Age (years)	20 (range, 13–31)	30 (range, 17–43)
Followup (years)	7 (range, 3–9)	4.5 (range, 2–12)
Height (cm)	166	165
Weight (kg)	62	70

Our records contained the preoperative and postoperative Merle d'Aubigné scores and WOMAC scores at final followup. To identify if differences existed in the behavior of ischial and pubic fractures, we divided the entire population into two groups. We recorded the duration of symptoms and time until healing of the fractures.

All patients had preoperative and postoperative anteroposterior pelvic radiographs. The lateral center-edge angle of Wiberg was measured [29]. Presence and grade of osteoarthritis were assessed on anteroposterior radiographs

and classified according to the method of Tönnis. Hip congruency was evaluated by means of abduction internal rotation views (von Rosen view) and classified according to the method described by Yasunaga et al. [30]. To evaluate anterior coverage of the femoral head, the anterior center-edge angle as described by Lequesne and Dijon was measured on false-profile views [12]. An observer (JS) other than the operating surgeon evaluated all radiographs after initial training by one of the senior authors (YJK).

Before PAO, all patients had substantial and progressive hip/groin pain impairing activities of daily living and refractory to nonoperative measures for at least 6 months before surgery; a lateral center-edge angle less than 20° and an acetabular index greater than 10° measured on standardized conventional anteroposterior pelvic radiographs; an anterior center-edge angle less than 25° as assessed on the false-profile view; improvement of acetabular coverage with abduction and internal rotation of the hip; and absence of severe osteoarthritis (Stage 3). Intraoperative anteroposterior pelvic radiographs were taken to check the position of the acetabular fragment and to ensure absence of iatrogenic fracture of either the ischium or inferior ramus of the os pubis. The postoperative rehabilitation protocol for PAO consisted of one-sixth body weight protected weightbearing for 6 to 8 weeks postoperatively. Once there was evidence of bony healing, the patient was advanced to weightbearing as tolerated. Weaning to one crutch and finally to no crutches followed.

Diagnosis of fractures was based on the clinical complaints and verified with conventional anteroposterior pelvic radiographs. When needed, computed tomography was performed to evaluate the existence and extent of possible nonunion to plan for adequate revision surgery. All patients who sustained a fracture initially were treated nonoperatively. This consisted of observation while allowing weightbearing as tolerated. Patients with painful nonunions who did not show improvement in symptoms with nonoperative treatment were considered candidates for revision surgery. Revision surgery consisted of bone grafting with or without internal fixation.

We used a nonparametric paired t-test to ascertain whether the functional outcome variables (Merle d'Aubigné score) changed with time (preoperative to final postoperative followups) in patients with fractures of the os pubis (SPSS v15, Chicago, IL). A nonparametric distribution was assumed. Because of the small number of patients in the group with ischium fractures, we performed no statistical analysis.

Results

All five patients with ischial fractures reported perineal or ischial pain exacerbated by sitting; this pain was distinctly different from the more proximal and anterior discomfort associated with the PAO. One patient presented with pain of insidious onset after weaning from crutches 6 months after surgery. The other four patients had pain when they started initial weightbearing in the days after surgery. All ischial fractures were identified on followup radiographs; they were not present on intraoperative fluoroscopy images. All patients ($n = 5$) initially were treated nonoperatively; however, two patients eventually underwent additional surgery. One patient underwent débridement, bone grafting, and plating for treatment of a symptomatic and disabling nonunion 30 months postoperatively. Symptoms resolved after this intervention; however, 4 months later, new pain occurred now radiating down the posterior thigh. We presumed this new pain was caused by entrapment of the sciatic nerve in scar tissue and performed a nerve release and removal of the plate with resolution of symptoms. Another patient was treated with curettage and bone grafting without stabilization soon after detection of fracture, which was associated with large cysts. Subsequent plate fixation was performed 32 months later as a result of a persistent symptomatic nonunion (Fig. 2). Both patients achieved complete healing of their nonunions after surgical stabilization. The remaining three patients did not require additional surgery but all had asymptomatic nonunions after a mean of 13 months.

Among the 12 patients with a pubis fracture, 10 had isolated inferior ramus fractures and two combined superior and inferior rami fractures. All patients in the pubic fracture group reported groin pain localized close to the symphysis. Pain was pronounced with sitting and was distinct from the more lateral symptoms resulting from the PAO. All patients had pain of insidious onset first noted after weaning from two crutches to one crutch at a mean of 3 months after surgery. One patient underwent bone grafting and refixation with healing of the fracture. All fractures but one were healed radiographically after a mean of 14 months (Fig. 3). The duration of symptoms averaged 10 months. The only nonunion in this patient population remained asymptomatic.

Patients with ischial fractures (average, 25 months, range, 12–34 months) required almost twice the amount of time to recover compared with those with pubic fractures (average, 10 months, range, 3–20 months). The mean times to union of ischial (15 months) and pubic (14 months) fractures were similar. Two of five patients with ischial fractures had painful nonunions and underwent subsequent surgery, whereas only one patient of 12 with pubic fractures had subsequent surgery.

Despite these complications, at final followup, both groups had similar clinical outcomes, patients with ischial fractures had slightly more pain than those with pubic fractures (Table 2).

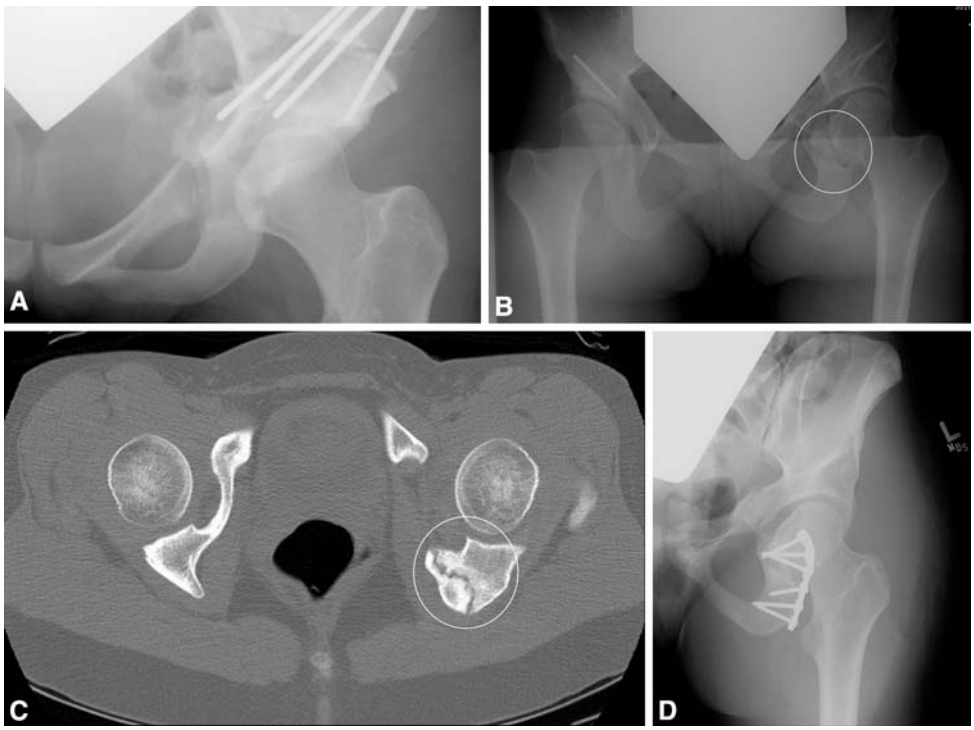

Fig. 2A–D (**A**) A radiograph obtained immediately after PAO shows an intact ischium. (**B**) An anteroposterior radiograph of the pelvis reveals an ischial fracture after periacetabular osteotomy. (**C**) The patient had a painful nonunion as confirmed on the axial computed tomography scan. (**D**) The postoperative anteroposterior radiograph shows the state after open reduction with internal fixation of an ischial fracture.

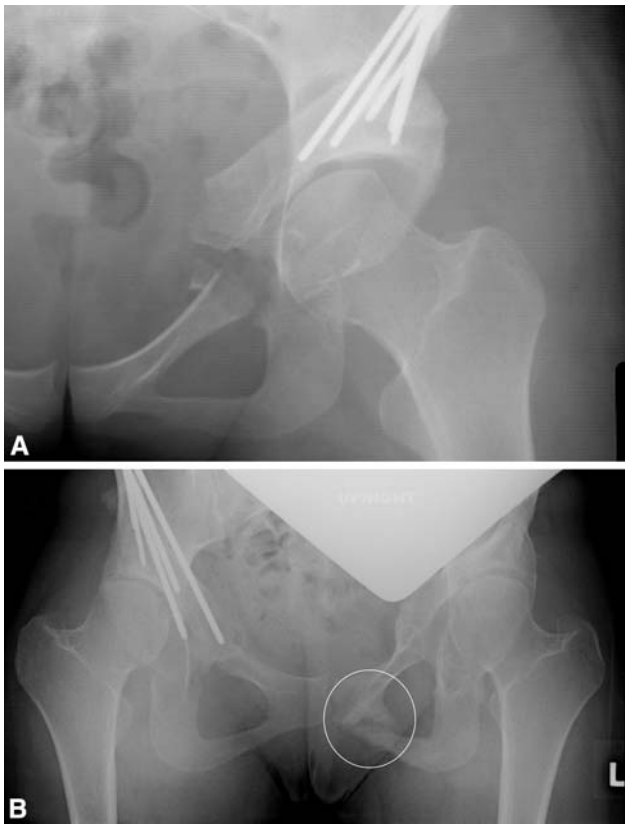

Fig. 3A–B (**A**) A radiograph obtained immediately after the PAO shows an intact inferior ramus. (**B**) An anteroposterior radiograph shows an inferior pubic ramus fracture after periacetabular osteotomy.

The Merle d'Aubigné score in the group with ischium fractures improved from 13 points preoperatively to 16 points at final followup (Table 2). Range of motion barely changed, but we observed improvement in pain and walking ability. Similarly, the group with pubic fractures increased ($p = 0.0003$) in Merle d'Aubigné score from 13 points preoperatively to 16.4 points postoperatively (Table 2). Similar to the ischial fracture group, the major improvement was the result of a higher (better) pain score.

None of the patients showed loss of fragment position. The measured lateral and anterior center-edge angles (reflecting the amount of correction) of both groups corresponded well with normal reported values. Also, there was no difference in progression of arthrosis (Table 3).

Discussion

Little is known regarding the influence of extraarticular fractures on outcome in patients who have undergone PAO. Based on our experience, we hypothesized the clinical presentation and interventions required for resolution would differ between pubic and ischial fractures, but if properly treated would yield equally good clinical outcomes despite the extraarticular fractures.

The major limitations of our study are its retrospective nature and the inability to compare both groups because of small population size (group with ischial fractures). Furthermore, the presentation and treatment methods were

Table 2. Clinical results

Fracture site	Clinical outcome	Domain	Preoperative	Postoperative	Significance (p)
Ischium (n = 5)	Merle d'Aubigné Mean (range)	Total	13 (11–16)	16 (13–18)	—
		Pain	3.5 (2–5)	4.7 (4–6)	
		ROM	5.3 (4–6)	5.5 (4–6)	—
		Walking	4.5 (4–5)	5.5 (5–6)	—
	WOMAC	Pain		12	—
		Stiffness		4	—
		Function		15	—
Pubis (n = 12)	Merle d'Aubigné Mean (range)	Total	13 (11–16)	16.4 (17–18)	0.0003
		Pain	2.4 (1–5)	5.3 (4–6)	0.0008
		ROM	5.5 (4–6)	5.9 (5–6)	NS
		Walking	5.3 (4–6)	4.9 (4–6)	NS
	WOMAC	Pain		4	—
		Stiffness		2	—
		Function		10	—

ROM = range of motion; NS = not significant; — = number too small for statistical analysis.

Table 3. Radiographic results

Fracture site	Radiographic measure	Preoperative	Postoperative	Significance (p)
Ischium	Tönnis grade	0	1	0	
		I	3	3	
		II	1	2	
		III	0	0	
		Mean (range)	1 (0–2)	1.4 (1–2)	0.2
	Joint congruency	Excellent	1	0	
		Good	3	4	
		Fair	1	1	
		Poor	0	0	
	LCE	Mean (range)	−4 (−27–10)	30 (29–32)	0.01
	ACE	Mean (range)	3 (−20–21)	27 (12–30)	0.02
Pubis	Tönnis grade	0	3	0	
		I	7	8	
		II	2	4	
		III	0	0	
		Mean (range)	0.8 (0–2)	1.3 (0–2)	0.05
	Joint congruency	Excellent	1	1	
		Good	9	7	
		Fair	2	4	
		Poor	0	0	
	LCE	Mean (range)	−5 (−29–12)	24 (0–30)	< 0.0001
	ACE	Mean (range)	−4 (−34–0)	26 (3–42)	< 0.0001

LCE = lateral center-edge angle; ACE = anterior center-edge angle.

heterogeneous; therefore, we could not stratify patients by categories other than type of fracture, and we caution readers in extrapolating from these case experiences.

Although the majority of patients eventually had good clinical outcome scores, they experienced long durations of symptoms related to either the ischial or pubic fractures. One of the striking findings was patients with ischial fractures after PAO had a longer recovery period and a greater tendency to undergo subsequent surgery to treat painful nonunions (two of five). Because of the ischium's

strong bony architecture, fractures of the ischium rarely are reported [18, 25]. Some authors have described iatrogenic intraoperative ischial fractures resulting from extension of the osteotomy into the sciatic notch and only a small number of them had specific surgical treatment [7, 8, 28]. In our study, the incidence of ischial fractures was extremely low (0.9%), suggesting the polygonal shape of the PAO is not the root cause of the ischial fractures. Technical difficulties during surgery remain the most likely explanation; it is plausible substantial weakening of the bone could occur while performing the ischial cuts during the PAO if too narrow a bridge of the posterior column is left intact.

In contrast, fractures of the os pubis seem less problematic than those of the ischium. Although stress fractures of the os pubis have been described in active young individuals and patients after THA, they have not been described in patients after PAO [2, 10, 11, 17]. None of the patients in our study had signs of osteoporosis or an elevated risk to sustain a fracture. There also was no evidence to confirm any major trauma preceding the fractures. The possibility of iatrogenic causes for pubic stress fractures is unlikely because these occurred far from the area of surgical dissection. All but two fractures healed uneventfully with nonoperative treatment. One patient had an asymptomatic nonunion, whereas another underwent additional surgery (grafting and plating). Nonetheless it took approximately 1 year to achieve total relief of symptoms; the time until complete pain relief and full resumption of activities was shorter than for patients with ischial fractures. This finding contradicts the estimated 3-month duration of pain reported by others [6, 13, 17, 20], although it corresponds to results for patients with pubic ramus insufficiency fractures after THA [2, 10, 24].

Small stature, younger age, Caucasian, and female gender have been reported as risk factors for pubic ramus fractures in the general population [1, 15, 20, 22]. Similarly, the majority of patients who sustained pubic fractures after PAO fit these criteria. Additionally, in all such patients, we found a very narrow inferior ramus. This could provide a possible explanation for how the inferior pubis ramus fractured. Normally, load transfer through the obturator ring is higher in the superior pubic ramus than in the inferior ramus. However, because the superior ramus is osteotomized during PAO, load transmission can occur only through the inferior pubic ramus and the ischium. This increased load could lead to additional strain, which then could initiate a fracture of the inferior ramus or the ischium [9].

Both groups had similar preoperative clinical and radiographic parameters (Tables 1–3). Therefore, we are unable to provide additional insight into the pathomechanics and identify risk factors for these stress fractures. Because there were no documented injuries preceding the fractures, it must be assumed normal loads were enough to fatigue the bone. Fortunately, the surgical correction achieved by PAO was not negatively influenced by the fractures.

Although fractures of the ischium and pubis after PAO are rare, surgeons must be aware of anatomic variants as specific risk factors and recognize the possible need for additional surgery. This is particularly important in the case of fractures of the ischium, which appear to be associated with an increased period of substantial morbidity.

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