

## Analysis of Nonunion of the Superior Pubic Ramus Osteotomy Site After Curved Periacetabular Osteotomy

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### Abstract

**Background/ aim:** We have been performing periacetabular osteotomy (PAO) to treat acetabular dysplasia with good short- and mid-term outcomes. Minor complications may occur, such as nonunion of the superior pubic ramus and stress fracture of the inferior pubic ramus. In this study, we investigated the risk factors for nonunion of the superior pubic ramus.

**Materials and Methods:** We studied 70 patients (three male, 67 female; mean age, 36.0 years; range, 16–63 years) who were diagnosed with acetabular dysplasia (Tönnis grade 0–2) and underwent PAO from October 2011 to April 2013. We evaluated each patient's age, center-edge angle improvement, body mass index, bone mineral density, and distance of the superior pubic ramus osteotomy. The shortest distances in vacancy of the pubic ramus osteotomy site were measured on computed tomography images. Statistical analyses were conducted using the Mann–Whitney U test and multiple logistic regression analysis. Statistical significance was set at  $P < 0.05$ .

**Results:** Fifteen hips exhibited nonunion of the superior pubic ramus; all were asymptomatic. The average age at surgery was 42.6 years in the nonunion group and 34.5 years in the union group. There were three male and 52 female patients in the union group and 15 female patients in the nonunion group. The average body mass index was 24.5 kg/m<sup>2</sup> in the nonunion group and 22.0 kg/m<sup>2</sup> in the union group. The average bone mineral density was 95.4% in the nonunion group and 92.0% in the union group. The average distance of the pubic ramus osteotomy site was 4.38 mm in the nonunion group and 1.36 mm in the union group. The mean center-edge angle change was 27.2° in the nonunion group and 31.7° in the union group. The distance of the superior pubic ramus osteotomy site significantly affected the development of nonunion ( $P = 0.003$ ). The mean Harris hip score improved from 73.6 points preoperatively to 93.6 points postoperatively.

**Conclusion:** We investigated the risk factors for nonunion of the superior pubic ramus. The distance of the superior pubic ramus osteotomy site significantly affected the development of nonunion.

**Key words:** Curved Periacetabular Osteotomy, Non-union, Superior Pubic Ramus

### Background/ aim

We have been performing periacetabular osteotomy (PAO) to treat acetabular dysplasia with good short- and mid-term outcomes. However, minor complications of PAO may occur, including nonunion of the superior pubic ramus, stress fracture of the inferior pubic ramus, abscess formation associated with the superficial sutures, and

transient lateral femoral cutaneous nerve numbness.<sup>1-12</sup>

We have been performing PAO to treat symptomatic acetabular dysplasia in adolescents and adults since 1995. A direct anterior approach is used for surgical exposure, and no exposure of the outer table of the pelvis is required (as in the modified Ganz procedure). A spherical osteotomy of the acetabulum (modified rotational acetabular osteotomy) is created during performance of curved PAO (CPO).

A number of severe or minor complications may occur

in accordance with the deterioration in the grade of osteoarthritis with time, and these complications may influence the longer-term outcomes of PAO.<sup>13-18</sup> Although several reports on the complications of PAO have been published, stress fractures occurring in the pubic and ischial bones are less well recognized. Nonunion of the superior pubic ramus is a relatively frequent complication of CPO. However, to our knowledge, there are no reports on nonunion of the superior pubic ramus. Some reports have stated that nonunion of the superior pubic ramus causes stress fractures of the ischial bone secondary to disruption of continuity. Therefore, it is necessary to clarify the incidence and causes of nonunion of the superior pelvic ramus and thereby determine whether this nonunion affects the clinical outcomes and radiographic results.

The purpose of this study was to analyze the incidence of and risk factors for nonunion of the superior pubic ramus after CPO.

### Materials and Methods

We retrospectively reviewed 474 symptomatic hips that had undergone CPO from August 1995 to December 2013. We studied 70 patients (three male, 67 female; mean age, 36.0 years; range, 16–55 years) who were diagnosed with acetabular dysplasia (Tönnis grade 0–2) and underwent PAO from October 2011 to April 2013.

The average follow-up duration at the most recent physical examination was 24 months (11–36 months). All patients presented with symptoms of hip dysplasia for at least 5 months, and all exhibited intact joint congruency on an anteroposterior radiograph of the hip at maximum abduction. Active motion exercises were initiated on the first postoperative day. Partial weight-bearing (10 kg) using two crutches or a walker was allowed on the third postoperative day, and full weight-bearing was allowed after 8 weeks postoperatively. The patients had anteroposterior pelvic radiographs taken immediately postoperatively and at 2 weeks, 1 month, 3 months, 6 months, and 1 year postoperatively, with the per year taken therefore.

Clinical evaluations were performed using the Harris hip score both preoperatively and postoperatively. Patients were excluded from the study if they were not observed for at least 1 year postoperatively. The following parameters were investigated: presence of a postoperative pubic/ischial stress fracture, sex, age, center-edge angle improvement, body mass index, bone mineral density (BMD), and distance of the superior pubic ramus osteotomy. The

shortest distances in vacancy of the pubic ramus osteotomy site were measured on computed tomography (CT) images. The patients were scanned with a dual-energy X-ray absorptiometry system (QTC4500A; Hologic) preoperatively and at 3 months and 1 year postoperatively. The BMD was measured at the femoral neck.

We measured the narrowest part of the CT slice during assessment of the vacancy of the osteotomy site of the pelvic ramus. CT imaging was performed 1 week postoperatively. CT slices were taken at 5-mm intervals in the coronal view (Fig. 1).



**Fig. 1** The shortest distances in vacancy of the pubic ramus osteotomy site were measured on computed tomography (CT) images.

The indications for CPO included acetabular dysplasia with symptoms for >5 months, a lateral center-edge angle of <16°, and improvement in joint congruency in the abducted position on anteroposterior radiographs.<sup>19,20</sup> The severity of the secondary osteoarthritis before CPO was graded using the Tönnis classification system. Specifically, hips with subchondral sclerosis were classified as grade 1, hips with subchondral cyst formation and partial cartilage interval narrowing were classified as grade 2, hips with severe or complete but localized cartilage interval narrowing were classified as grade 3, and hips with extensive and severe complete cartilage interval loss were classified as Grade 4.<sup>21</sup> The CE angle according to Wiberg<sup>22</sup> was measured on the preoperative and most recent anteroposterior radiographs. This type of osteotomy is not recommended for patients with aggravated joint congruency in the abducted position. Patients with a history of operations were excluded from the study. All surgical procedures were performed by two senior authors (M.N., Y.N.). All radiographic measurements were made three times on different occasions by three authors who were blind to the clinical

results, and the average values were calculated.

### Statistical analysis

Statistical analyses were conducted using the Mann-Whitney U test. Statistical significance was set at  $P < 0.05$ . Values of  $P < 0.05$  were considered to indicate statistical significance. All statistical analyses were performed using SPSS v.20 (SPSS Inc., Chicago, IL).

## Results

The average age of the patients at the time of surgery was 35.9 years (range, 16–63 years), and the average follow-up duration was 24 months (range, 11–36 months). The average body mass index was  $22.4 \text{ kg/m}^2$  (range,  $17.1\text{--}33.2 \text{ kg/m}^2$ ). The mean Harris hip score improved from 73.6 (range, 47–93) points preoperatively to 93.5 (range, 68–100) points postoperatively. No surgery-related deep infections, vascular injuries, or motor nerve palsies occurred.

Fifteen hips exhibited nonunion of the superior pubic ramus, and all were asymptomatic. We divided these patients into two groups: the union group and nonunion group. The results are shown in Table 1, 2. The average age at surgery was 42.6 years in the nonunion group and 34.5 years in the union group. There were three male and 52 female patients in the union group and 15 female patients in the nonunion group. The average body mass index was  $24.5 \text{ kg/m}^2$  in the nonunion group and  $22.0 \text{ kg/m}^2$  in the union group. The average BMD was 95.4% in the nonunion group and 92.0% in the union group. The average distance of the pubic ramus osteotomy site was 4.38mm in the nonunion group and 1.36 mm in the union

group. The mean center-edge angle change was  $27.2^\circ$  in the nonunion group and  $31.7^\circ$  in the union group. The distance of the superior pubic ramus osteotomy site significantly affected the development of nonunion ( $P = 0.003$ ).

No hips underwent concomitant open osteochondroplasty (plasty of the femoral head-neck offset) through the same surgical approach to evaluate and address intra-articular pathology.

### Radiographic results

Significant radiographic improvement from the preoperative to the 2-year follow-up evaluations was seen in all hip dysplasia parameters (Table 2). The mean center-edge angle improved from  $9.3^\circ$  (range,  $-1^\circ$  to  $19^\circ$ ) preoperatively to  $32.0^\circ$  (range,  $15^\circ\text{--}49^\circ$ ) postoperatively ( $P < 0.01$ ). The mean sharp angle improved from  $48.7^\circ$  (range,  $41^\circ\text{--}59^\circ$ ) preoperatively to  $37.3^\circ$  (range,  $23^\circ\text{--}45^\circ$ ) postoperatively ( $P < 0.01$ ). The mean acetabular index of the weight-bearing zone improved from 60.5 (range, 48–71) preoperatively to 87.9 (range, 79–100) postoperatively ( $P < 0.01$ ). (Table 3) Preoperatively, 65 hips had no signs of osteoarthritis (grade 0 according to the Tönnis classification), while four hips demonstrated early joint space narrowing or early osteophyte formation (grade 1), one hip had moderate joint space narrowing and moderate loss of head sphericity (grade 2), and no hips had complete loss of articular cartilage (grade 3). At the time of the final follow-up, 62 hips were Tönnis grade 0, 6 hips were grade 1, and 2 hips were grade 2. (Table 4)

### Subsequent surgeries

The only subsequent minor surgery included screw removal in 48 patients. No major surgeries were required,

**Table 1.** Clinical evaluation

	preoperative	Final follow up	P value
union group	73.9(57–86)	93.8(72–100)	<0.01*
non-union group	69.6(47–93)	90(68–100)	<0.01*

Mann-Whitney U test

**Table 2.** Factor

	union group	non-union group	P value
center-edge angle change	31.7(11–39.8)	27.2(19.4–39.1)	0.46
BMD	92(64–133)	95.4(66–117)	0.47
BMI	22(17.0–32.8)	24.5(17.7–33.2)	0.12
distance of the pubic ramus osteotomy site	1.36(0–5.7)	4.38(0–7.1)	<0.01*
age	34.5(16–63)	42.6(28–55)	0.21

Mann-Whitney U test

such as total hip arthroplasty, revision of the hip, or reosteotomy.

#### Case reports

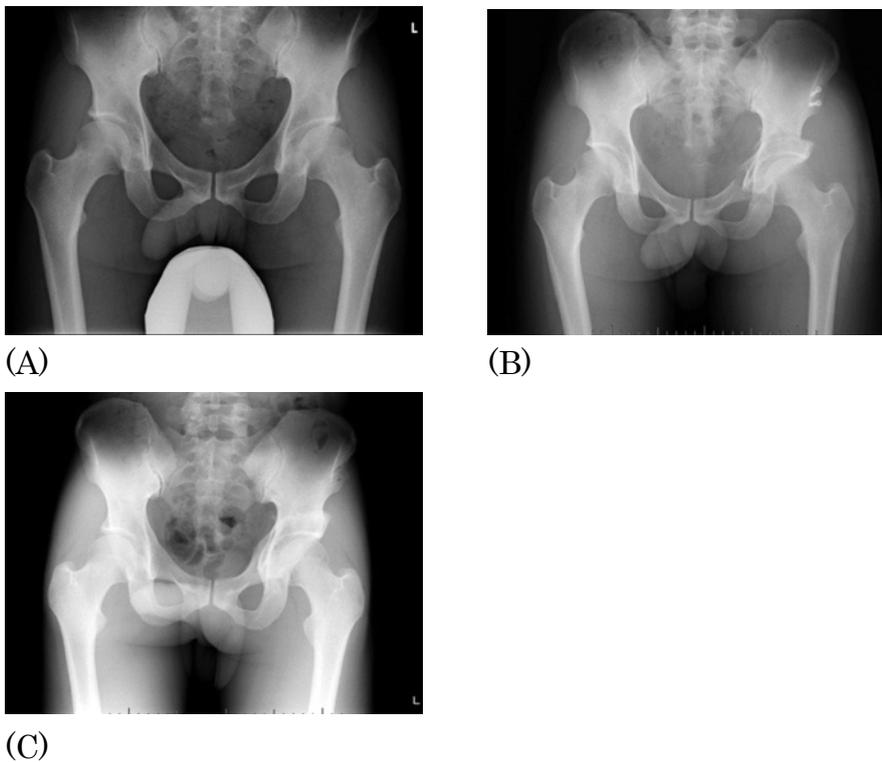
##### Case 1

A 44-year-old man had suffered from left hip pain on walking. Although he did not have a history of congenital dislocation of the hip, the AP radiograph showed acetabular dysplasia (Fig. 2A). He underwent CPO (Fig. 2B). His Harris hip score improved from 88 points preoperatively to 99 points postoperatively. The radiograph at 2 years after

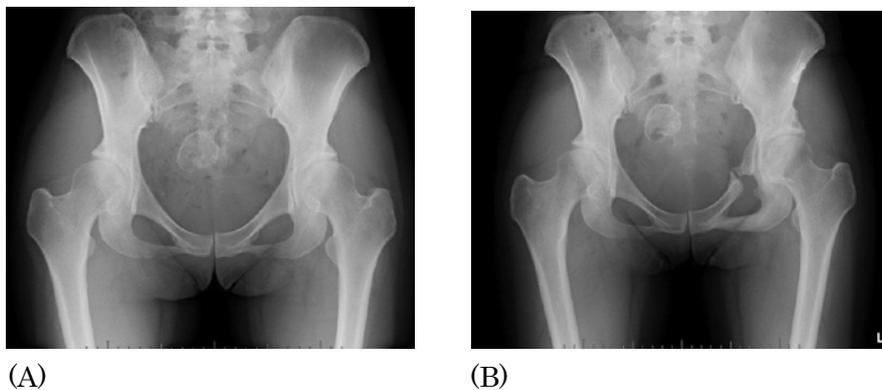
CPO shows union of the superior pubic ramus (Fig. 2C).

##### Case 2

A 48-year-old woman had left hip pain since the age of 40 years. The AP radiograph showed acetabular dysplasia of the both hips (Fig. 3A). CPO was performed on the left hip, after which joint congruency was improved. Although the radiograph at 2 years after CPO showed non-union of the superior pubic ramus (Fig. 3B). Harris hip score improved 75 points preoperatively to 96 points postoperatively.



**Fig. 2** (A) Preoperative, (B) a week postoperative and (C) 2-year postoperative AP radiographs showing the hips of 44-year old patient with hip dysplasia. There was union of the superior pubic ramus.



**Fig. 3** (A) Preoperative, (B) a week postoperative and (C) 2-year postoperative AP radiographs showing the hips of 48-year old female with hip dysplasia. There was non-union of the osteotomy site of the superior pubic ramus.

## Discussion

PAO has become one of the most successful procedures for the treatment of hip dysplasia in adults and adolescents. Many reports have described good clinical results of PAO. CPO is also effective for the correction of hip dysplasia. In this series, the mean postoperative Harris hip score was significantly better than the preoperative score.

However, some reports have described complications of PAO. Major complications include avascular necrosis of the femoral head or acetabulum, sciatic or femoral nerve palsy, major bleeding, peroneal neuropraxia, and fracture of the posterior column. Minor complications include hematoma formation, delayed wound closure, dysesthesia of the lateral femoral cutaneous nerve, heterotopic ossification, urinary tract infection, and postoperative fever.

Several reports have described the clinical outcomes and complications of PAO. To the best of our knowledge, however, there are no reports on the causes of or risk factors for nonunion of the osteotomy site of the superior pelvic ramus. Certainly, almost all cases of nonunion of the superior pelvic ramus are asymptomatic and have no effects on the clinical outcome, as mentioned above. However, it has been reported that discontinuity of the pelvic ring may cause stress fractures of the inferior pelvic ramus with prolonged groin pain.<sup>23</sup>

We evaluated each patient's age, center-edge angle improvement, body mass index, BMD, and distance of the superior pubic ramus osteotomy. The distance of the superior pubic ramus osteotomy was the only factor for which there were significant differences between the two groups. It is possible that not every fracture was actually recognized as a complication in some reports; thus, the incidence, risk factors, and treatment outcomes for fractures are not yet clear. Kralj et al.<sup>24</sup> stated that a longer follow-up duration would probably reveal further

deterioration, even in hips with initially successful outcomes. Norman<sup>25</sup> described extra-articular fractures of the pelvic ring after PAO. We identified the prevalence of nonunion of the osteotomy site of the superior pelvic ramus from another paper and found that the prevalence of nonunion was almost identical to our results.

As described above, no significant differences in the clinical scores were observed between the union group and nonunion group either before the operation or at the time of the final follow-up. However, some reports have identified a relationship between nonunion of the superior pubic ramus and stress fractures of the inferior pubic ramus.<sup>13,26</sup>

It is very important to clarify the risk factors, incidence, and treatment outcomes of such fractures. Tuboi et al. reported that pubic discontinuity was observed in 8 of 10 hips (80.0%) in the fractured group but in only 15 of 330 hips (4.5%) in the nonfractured group<sup>23</sup>. They considered that all cases of pubic discontinuity resulted in nonunion at the time of the final follow-up. They also found no significant differences in the total score or the scores for pain, gait, range of motion, or activities of daily living between the two groups either before the operation or at the time of the final follow-up. In the present study, the distance of the osteotomy side was the only statistically significant factor in Mann-Whitney U test ( $P < 0.0001$ ).

Patients with discontinuity at the osteotomy site of the superior pelvic ramus are at risk for stress fractures of the inferior pelvic ramus or ischium after CPO. Hence, it is important to avoid nonunion of the osteotomy site of the pubic ramus. Although most patients eventually had good clinical outcome scores, they experienced long durations of symptoms related to either the ischial or pubic fractures.

We measured BMD preoperatively, 3 months postoperatively, and 1 year postoperatively in this study. We hypothesized that patients with a low BMD were more likely to have nonunion at the osteotomy site of the superior

**Table 3.** Radiographic evaluations

	preoperative	postoperative	P value
Center - Eadge angle	9.3° (range, -1° to 19°)	32.0° (range, 15°-49°)	< 0.01*
sharp angle	48.7° (range, 41°-59°)	37.3° (range, 23°-45°)	< 0.01*
acetabular index	60.5 (range, 48-71)	87.9 (range, 79-100)	< 0.01*

Mann-Whitney U test

**Table 4.** Severity of osteoarthritis

Tönnis	Number of preoperative hips	Number of postoperative hips
0	65	62
1	4	6
2	1	1
3	0	2
4	0	0

pelvic ramus and a stress fracture at the inferior pelvic ramus than were patients with a high BMD. However, no significant differences were observed. This result may have been obtained because the number of patients was small. Hence, more cases are needed in future studies. The BMD is expected to be lower postoperatively than preoperatively. The patients in this study underwent rehabilitation and returned to their daily lives after surgery, and their BMD at 1 year postoperatively recovered to the preoperative level.

The patients in this study were <65 years old, which is relatively young. Thus, few patients had severe osteoporosis. Based on the results of this study, we do not consider that it is always necessary to treat the osteoporosis in such patients; instead, treatment should be considered in accordance with the individual patient's situation.

No significant changes in BMD and no biological effects on bone remodeling caused by a changed loading pattern in the acetabulum were detected. Additionally, there was no significant correlation between BMD and migration of the acetabulum.

We have used various devices to prevent nonunion. Since 2005, we have performed pubic osteotomies using an inclination of 30° to the horizontal line.<sup>27</sup> The advantages of this method are not only medialization of the femoral head and easy rotation of the acetabular fragment, but also the possibility of preventing nonunion because the osteotomy site has a large contact area. Moreover, since 2012, we have performed a tipping technique and carried out decortication at the superior limb of the pubis to promote union. We transplant the bone meal that is removed when we make the groove to the osteotomy of the iliac bone.

A limitation of this study was that the number of patients was low; thus, examination of larger numbers of cases is necessary in the future. Despite the small number of nonunions, all hips exhibiting nonunion were asymptomatic, and nonunion had no influence on the clinical outcome at the final follow-up observation. Furthermore, some hips with delayed union exhibited union the following year. These results indicate that long-term observation is imperative.

In summary, surgeons must be aware that nonunion of the osteotomy site of the pubic ramus sometimes occurs after CPO, and measures should be taken to avoid this complication. The vacancy of the osteotomy site of the superior pubic ramus must be shortened to prevent nonunion.

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