Medium-Term Outcome of Periacetabular Osteotomy and Predictors of Conversion to Total Hip Replacement

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Background: Little is known about medium or long-term results of periacetabular osteotomy and which factors predict a poor outcome in terms of conversion to total hip replacement. The aims of this study were to assess the medium-term outcome following periacetabular osteotomy and to analyze what radiographic and patient-related factors predict a poor outcome.

Methods: One hundred and sixteen periacetabular osteotomies performed by the senior author from December 1998 to December 2002 were eligible for inclusion. Data were assessed through database inquiry and evaluation of radiographic material. The mean duration of follow-up was 6.8 years. At the time of follow-up, we conducted an interview, performed clinical and radiographic examinations, and asked the patients to complete the Western Ontario and McMaster Universities Osteoarthritis Index and the Short Form-36 questionnaires. We performed a Kaplan-Meier survival analysis, and we used a Cox proportional hazards model to identify factors predicting a poor outcome.

Results: With conversion to total hip replacement as the end point, the Kaplan-Meier analysis showed a hip survival rate of 81.6% (95% confidence interval, 69.7% to 89.3%) at 9.2 years. At the time of follow-up, the median physical component score on the Short Form-36 was 48.31, the median mental component score on the Short Form-36 was 57.95, and the median Western Ontario and McMaster Universities Osteoarthritis Index total score was 84.44. The median pain score on the visual analog scale was 0 at rest and 1 after fifteen minutes of normal walking. When adjusting for preoperative osteoarthritis, we identified seven factors predicting conversion to total hip replacement. Preoperative predictive factors were severe dysplasia on conventional radiographs and computed tomographic scans, reduced acetabular anteversion angle on computed tomographic scans, and the presence of an os acetabuli (calcification of a detached labrum). Predictive factors identified on the immediate postoperative radiographs were a small width of the acetabular sclerotic zone and excessive lateral and proximal dislocation.

Conclusions: Periacetabular osteotomy can be performed with a good outcome at medium-term follow-up, suggesting that it may be applied by experienced surgeons with satisfactory results. To further improve the outcome, focus should be on the potential negative influence of parameters that are easily assessed, such as the preoperative grade of osteoarthritis, the presence of an os acetabuli, and severe acetabular dysplasia.

Level of Evidence: Prognostic Level II. See Instructions to Authors for a complete description of levels of evidence.

The periacetabular osteotomy described by Ganz et al.[1] is used worldwide as a joint-preserving treatment in young adults with symptomatic acetabular dysplasia. The aim is to increase coverage of the femoral head by a three-dimensional reorientation of the acetabulum. The change in hip biomechanics is believed to delay or prevent the development of osteoarthritis[2-13].

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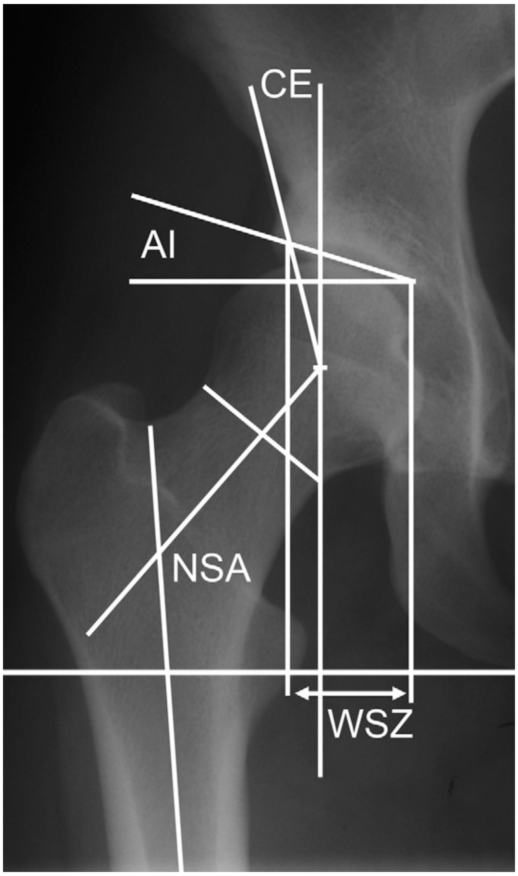

Fig. 1
Radiographic parameters showing the center-edge angle (CE), the acetabular index angle (AI), the neck-shaft angle (NSA), and the horizontal width of the sclerotic acetabular zone (WSZ).

An increasing number of studies have indicated that periacetabular osteotomy can be widely performed with success in terms of high rates of survival of the hip at short-term follow-up (less than a minimum follow-up of five years)[2,4,5,7,8,10-12]. Few studies have described the medium and long-term outcome of periacetabular osteotomy[3,9,13], and these were primarily from the Berne group on the outcome of the first consecutive series of patients[3,13]. Those studies indicated that periacetabular osteotomy has the ability to preserve hips for up to two decades in selected patients[13].

Little is known about which factors predict a poor outcome in terms of conversion to total hip replacement. There is, however, growing evidence that advanced stages of preoperative osteoarthritis predict a poor outcome following periacetabular osteotomy[2-4,9,13,14]. Other factors, such as increasing age and undercorrection of the deformity, have recently been suggested, but the actual effect, independent of concomitant osteoarthritis, is not clear[13]. Increased knowledge in this field has the potential to aid in the selection of patients to improve medium and long-term outcome of this osteotomy.

The aims of this study were to assess survivorship of the hip and the outcome at medium-term follow-up after periacetabular osteotomy and to identify demographic, clinical, and radiographic parameters that predict a poor outcome in terms of conversion to total hip replacement.

Materials and Methods

Through database inquiry and the evaluation of radiographs, we retrospectively assessed the initial experience of the senior author (K.S.) with periacetabular osteotomy. From December 1998 to December 2002, the senior author performed 121 periacetabular osteotomies in 100 patients. Data from all procedures were recorded in a database assigned to the Danish Hip Arthroplasty Register[15]. Prior to the procedures registered in the database, the senior author had performed approximately thirty periacetabular osteotomies. The

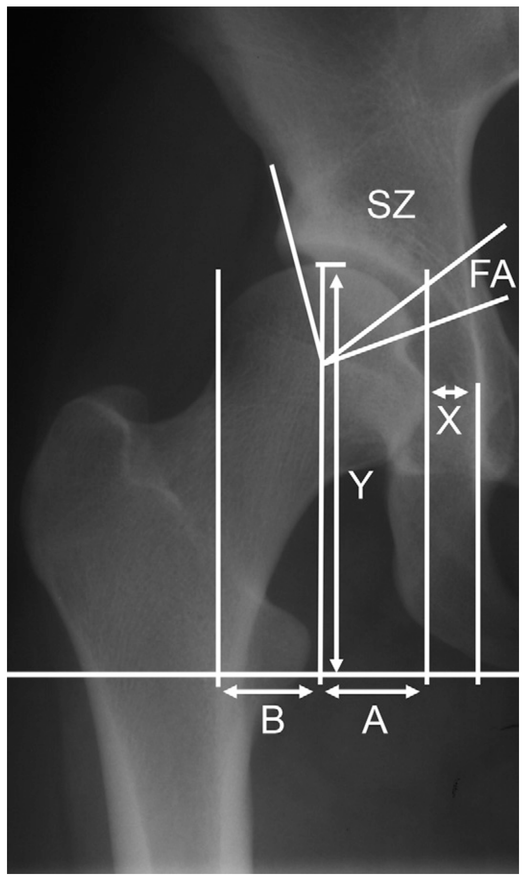

Fig. 2
Radiographic parameters showing the sclerotic zone angle (SZ) and the fovea-acetabular angle (FA), with one leg running through the most lateral limit of the fovea capitis femoris. The roundness index is calculated from A/(A + B). X indicates the distance from the ilioischial line to the medial limit of the femoral head, and Y indicates the distance from the line of reference to the most proximal limit of the femoral head.

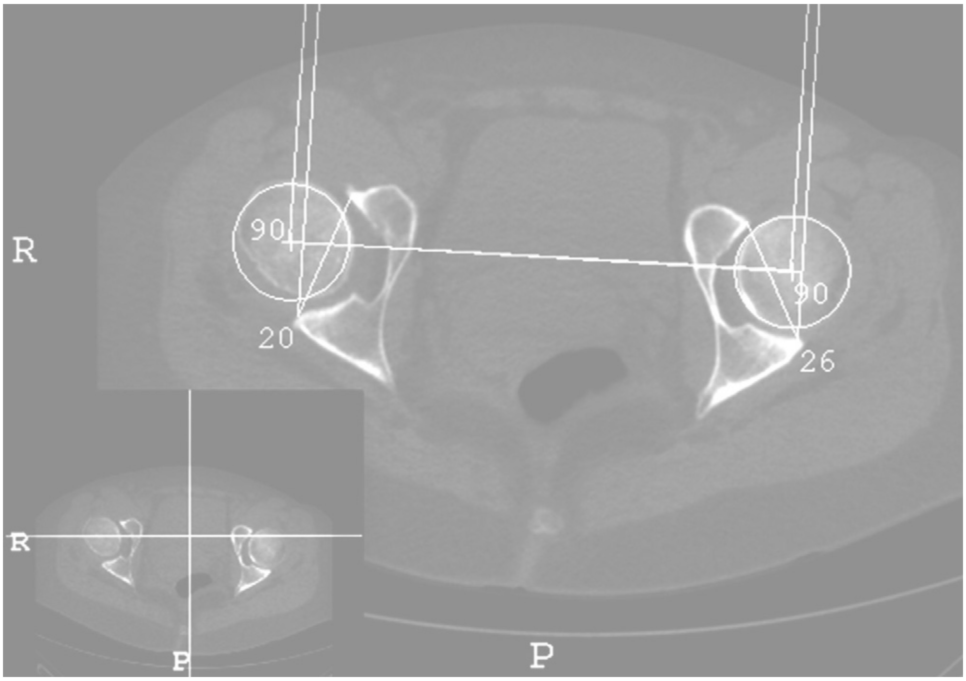

Fig. 3

Axial computed tomographic scan of the hips showing the assessment of the acetabular version angle. The reference planes are perpendicular (marked by 90°) and are defined by the line running between the center of the femoral heads. The acetabular version angle is formed by the line running from the anterior to the posterior aspects of the acetabular rim and from there parallel to the reference plane. The angles are 20° (right hip) and 26° (left hip). R = right side, and P = posterior.

indications for the osteotomy were symptomatic acetabular dysplasia defined by persistent pain, a center-edge angle of Wiberg[16] of <25°, a congruent hip joint, hip flexion of >110°, and internal rotation of >15°. Initially, there was less focus on the preoperative degree of osteoarthritis, but preferentially patients with a Tönnis grade[17] of 0 or 1 had surgery. All 121 procedures were eligible for inclusion. Five procedures performed in four foreign patients were excluded, because the patients were not available for follow-up. Thus, 116 periacetabular osteotomies in ninety-six patients comprised the study group.

In the study group, we assessed demographic, clinical, and preoperative and postoperative radiographic characteristics (Table I) through database inquiry and an evaluation of radiographs. The assessment of parameters on conventional anteroposterior pelvic radiographs made with the patient supine was done by one blinded observer (A.T.). The following parameters were assessed on both preoperative and postoperative radiographs: the center-edge angle[16], the acetabular index angle[17], the sclerotic zone angle[18], the fovea-acetabular angle[18], the horizontal width of the sclerotic zone, x coordinates[3] and y coordinates[19] of femoral head translation, the roundness index of the femoral head[20], the neck-shaft angle, the presence of an os acetabuli[21,22], the minimal joint-space width along the sclerotic zone, and the Tönnis grade of osteoarthritis[17]. Five preoperative and two postoperative radiographs were missing. The following parameters were assessed by a radiologist on the preoperative computed tomographic scan[23,24]: the anterior acetabular sector angle, the posterior acetabular sector angle, the acetabular version angle, the coronal center-edge angle, the sagittal center-edge angle, the neck-shaft angle, and the neck version angle. Three patients did not have a preoperative computed tomographic scan. All other patient-related parameters were available in the database. Due to missing information on weight or height, the body mass index was not available for sixteen of the ninety-six patients (eighteen of 116 hips). For the remaining parameters, data were complete.

Follow-up was performed during February and March 2008. Sixteen patients (seventeen hips) who had conversion to a total hip replacement were not assessed. The mean duration of follow-up was 6.8 years (range, 5.2 to 9.2 years). We conducted an interview to identify the primary location of the hip pain or discomfort; to determine the score on a visual analog scale for pain at rest and after fifteen minutes of normal walking; and to assess for clicking or locking of the hip joint, pain or discomfort related to the spine or lower extremities, subsequent hardware removal, and whether there had been a change of job since surgery because of hip problems. A clinical examination was performed to investigate the hip range of motion, the outcome of the impingement test (positive if groin pain was produced), and dysesthesias of the lateral femoral cutaneous nerve distribution. Radiographic examination consisted of a weight-bearing anteroposterior

TABLE I Demographic, Surgical, and Radiographic Characteristics of the Ninety-six Patients (116 Hips)

Demographic and surgical data	Preop.	Postop.
Age at time of operation *(yr)*		
Median (interquartile range)	29.9 (21.7-39.3)	
Range	14.1-57.0	
Sex distribution in procedures*		
Female	90 (78)	
Male	26 (22)	
Body mass index *(kg/m^2)*		
Mean (95% confidence interval)	23.8 (23.0-24.6)	
Range	15.1-36.7	
Diagnosis (reason for acetabular dysplasia)*		
Developmental dysplasia	84 (72)	
Congenital dislocation	18 (16)	
Legg-Calvé-Perthes disease	14 (12)	
Concomitant neuromuscular disorders*		
Poliomyelitis sequelae	2 (2)	
Cerebral palsy	1 (1)	
Down syndrome	2 (2)	
Charcot-Marie-Tooth disease	2 (2)	
Previous surgery*		
Intertrochanteric osteotomy	9 (8)	
Pelvic osteotomy	5 (4)	
Surgical approach*		
Ilioinguinal	110 (95)	
Modified Smith-Petersen	6 (5)	
Concomitant surgery*†		
Intertrochanteric osteotomy	7 (6)	
Cheilectomy	7 (6)	
Greater trochanter distal shift	3 (3)	
Tenotomy	1 (1)	
Radiographic characteristics‡		
Characteristics on pelvic radiographs		
Center-edge angle *(deg)*		
Median (interquartile range)	11 (5-19)	29 (23-34)
Range	−29-30	−8-52
Acetabular index angle *(deg)*		
Median (interquartile range)	20 (14-28)	8 (0-12)
Range	4-53	−7-46
Sclerotic zone angle *(deg)*		
Mean (95% confidence interval)	60 (59-62)	63 (61-64)
Range	34-82	32-102
Fovea-acetabular angle *(deg)*		
Mean (95% confidence interval)	−6 (−10 to −2)	14 (11-18)
Range	−57-32	−41-66
Horizontal width of the sclerotic zone *(cm)*		
Mean (95% confidence interval)	3.0 (2.9-3.1)	3.2 (3.1-3.3)
Range	1.9-4.6	1.9-5.1
X coordinate of femoral head translation *(cm)*		
Mean (95% confidence interval)	1.7 (1.6-1.8)	1.7 (1.6-1.8)
Range	0.9-3.3	0.2-3.3

TABLE I (*continued*)

Demographic and surgical data	Preop.	Postop.
Y coordinate of femoral head translation *(cm)*		
Mean (95% confidence interval)	10.2 (10.0-10.4)	9.8 (9.6-10.0)
Range	7.3-14.6	7.2-13.7
Roundness index of the femoral head		
Median (interquartile range)	0.54 (0.52-0.59)	0.55 (0.51-0.60)
Range	0.45-0.85	0.42-0.75
Neck-shaft angle *(deg)*		
Mean (95% confidence interval)	139 (137-141)	142 (140-144)
Range	103-161	111-163
Presence of os acetabuli*	13 (12)	13 (11)
Minimal joint space width *(mm)*		
Mean (95% confidence interval)	4.6 (4.4-4.9)	4.2 (4.0-4.4)
Range	1.5-8.9	0.7-7.1
Tönnis grade of osteoarthritis*		
0	56 (50)	55 (48)
1	44 (40)	48 (42)
2	11 (10)	9 (8)
3	0 (0)	2 (2)
Characteristics on computed tomographic scans§		
Anterior acetabular sector angle *(deg)*		
Mean (95% confidence interval)	45 (43-47)	
Range	13-73	
Posterior acetabular sector angle *(deg)*		
Mean (95% confidence interval)	85 (83-86)	
Range	62-105	
Acetabular version angle *(deg)*		
Mean (95% confidence interval)	20 (19-22)	
Range	−6-57	
Coronal center-edge angle *(deg)*		
Mean (95% confidence interval)	11 (9-13)	
Range	−15-40	
Sagittal center-edge angle *(deg)*		
Mean (95% confidence interval)	52 (49-54)	
Range	13-87	
Neck-shaft angle *(deg)*		
Mean (95% confidence interval)	139 (136-141)	
Range	105-168	
Neck version angle *(deg)*		
Mean (95% confidence interval)	31 (28-34)	
Range	−20-77	

*The values are given as the number of hips with the percentage in parentheses. †Some concomitant operations were combined in one procedure. ‡The preoperative data are from 111 pelvic radiographs, and the postoperative data are from 114 pelvic radiographs. §The data are from 113 computed tomographic scans.

pelvic radiograph to assess the crossover sign (crossing of the anterior and posterior acetabular rims)[19,25], the minimum joint-space width, and the Tönnis grade of osteoarthritis[17]. Further, patients were asked to complete the Short Form (SF)-36[26] (one per patient) and the Western Ontario and McMaster Universities Osteoarthritis Index (WOMAC)[27,28] (one per procedure) questionnaires. The physical and mental component scores were subsequently calculated from the SF-

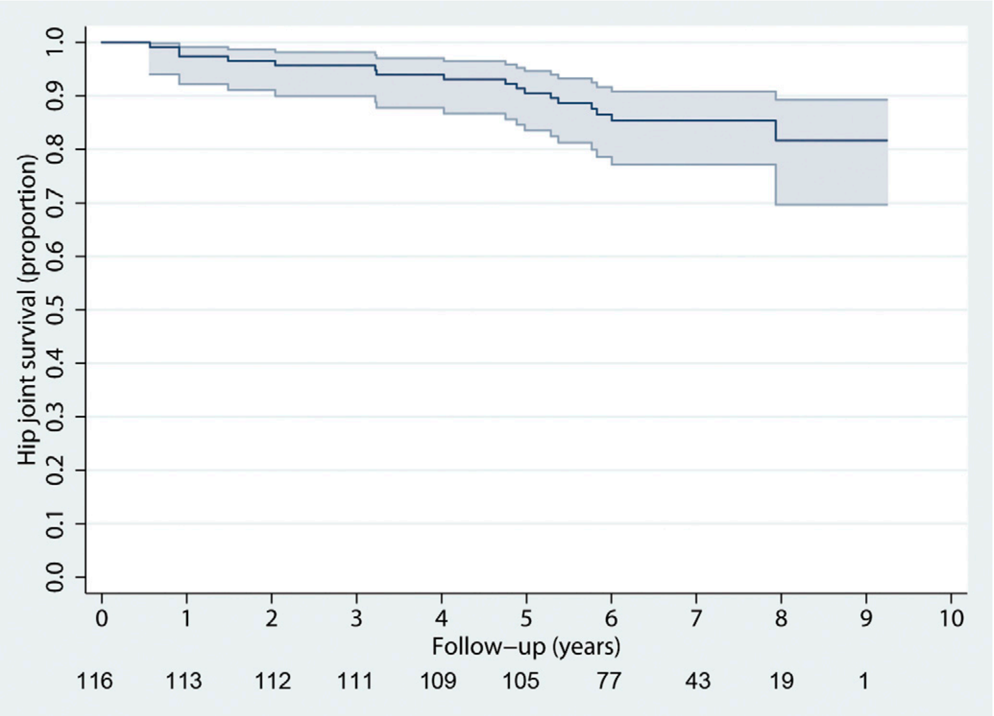

Fig. 4

Kaplan-Meier survivorship curve (and 95% confidence intervals), with conversion to total hip replacement as the end point, for 116 hips (ninety-six patients) after a periacetabular osteotomy. The number of hips remaining for every year of follow-up is given below the x axis. The mean duration of follow-up was 6.8 years (range, 5.2 to 9.2 years).

36 questionnaire[26]. Each subscale of the WOMAC score was normalized, taking into account differences in scale length, and the total score was normalized on a scale from 0 to 100, with 100 being the best possible score[27]. Of the ninety-nine remaining hips in eighty-one patients, seventy-seven hips in sixty-one patients were available at the time of follow-up (one pregnant patient did not have a radiograph made). For ten hips in nine patients, only questionnaires were returned, and twelve hips in eleven patients were not available for follow-up. The interviews and clinical examinations were done by three investigators (A.T., B.E., and K.S.). Assessments of the SF-36 and WOMAC scores and of the radiographic material were done by one investigator (A.T.).

Surgical Technique

The ilioinguinal approach was performed as previously described, but without lateral extension along the iliac crest[29]. Medial and lateral mobilization of the iliopsoas muscle, combined with medial retraction of the external iliac vessels, provided access to perform the osteotomies through two windows. A modified Smith-Petersen approach was used in six procedures. The skin incision was made along the anterior one-third of the iliac crest to the anterior superior iliac spine, where it curved distally and continued vertically along the tensor fasciae latae muscle for approximately 10 cm. In some of the procedures, the origin of the sartorius muscle was detached by means of an osteotomy; however, the rectus femoris was never detached. The internervous planes between the tensor fasciae latae and sartorius muscles, and the gluteus medius and rectus femoris muscles, were developed. A concomitant cheilectomy was performed in a few procedures; however, abnormalities of the labrum were not assessed with use of any of the approaches. The periacetabular osteotomies were located as described by Ganz et al.[1], and the reoriented acetabular fragment was fixed with use of two or three cortical screws. Patients were mobilized with partial weight-bearing using crutches for the first eight weeks postoperatively.

Statistical Analysis

Normally distributed data are presented as means with 95% confidence intervals, and data without normal distribution as medians with interquartile ranges. Kaplan-Meier survival of the hip, with conversion to total hip replacement as the end point, was estimated through an inquiry to the Danish Hip Arthroplasty Register[15] and a review of the patient records. By means of the Cox proportional hazards model, we analyzed the time-dependent association between possible predictors and the time to conversion to total hip replacement. Analyzed parameters were age at the time of surgery, sex, body mass index, diagnosis (that is, the reason for development of acetabular dysplasia), previous trochanteric and/or acetabular osteotomies, preoperative and postoperative parameters on

TABLE II Results of Follow-up Evaluation

Parameter	Results	Interquartile Range	Range
Interview and examination (n = 77)			
Primary localization of hip pain or discomfort*			
Groin	26 (34)		
Trochanter	7 (9)		
Buttock	3 (4)		
Femur	2 (3)		
Median pain score on visual analog scale			
At rest	0	0-1	0-7
After 15 min of normal walking	1	0-3	0-10
Clicking or locking of the hip joint*	19 (25)		
Pain or discomfort related to spine or lower extremities*			
Spine	21 (27)		
Knee	4 (5)		
Subsequent hardware removal*	14 (18)		
Change of job since surgery due to hip problems*	15 (19)		
Dysesthesia of the lateral femoral cutaneous nerve*	37 (48)		
Positive impingement test*	14 (18)		
Median range of motion *(deg)*			
Flexion	100	95-120	80-140
Extension	15	5-20	0-30
Abduction	45	40-50	20-60
Adduction	20	20-30	0-50
Internal rotation	15	10-30	0-45
External rotation	30	20-40	5-60
Questionnaires† (n = 87)			
Median physical component score on SF-36 (0-100)	48.31	39.34-54.65	15.50-59.12
Median mental component score on SF-36 (0-100)	57.95	51.39-61.07	18.14-68.54
Median WOMAC total score (0-100)	84.44	70.20-95.83	38.05-100.00
Weight-bearing pelvic radiograph (n = 76)			
Presence of crossover sign*	20 (26)		
Minimal joint-space width *(mm)*			
Mean	3.8		0.0-6.4
95% confidence interval	3.5-4.1		
Tönnis grade of osteoarthritis*			
0	24 (32)		
1	38 (50)		
2	8 (11)		
3	6 (8)		

*The values are given as the number of hips with the percentage in parentheses. †SF-36 = Short Form-36, and WOMAC = Western Ontario and McMaster Universities Osteoarthritis Index.

conventional radiographs (Figs. 1 and 2), and preoperative parameters on the computed tomographic scan (Fig. 3). We calculated both the crude hazard ratios for the possible predictors and the hazard ratios adjusted for the preoperative degree of osteoarthritis (with 95% confidence intervals). Application of log-log plots was used to test that the proportional hazards requirements were fulfilled. The level of significance was set at $p < 0.05$.

Source of Funding
During the conduct of this study, one author (A.T.) received a grant from the Danish Rheumatism Association.

TABLE III Crude and Adjusted Hazard Ratios in Significant Predictors of Poor Outcome

Parameter	Crude Hazard Ratio (95% Confidence Interval)	P Value	Adjusted Hazard Ratio (95% Confidence Interval)*	P Value
Demographic data				
Age of ≥45 yr at time of surgery	2.91 (1.07-7.93)	0.04	2.31 (0.78-6.81)	0.13
Radiographic data				
Preop. center-edge angle of <0°	3.31 (1.05-10.40)	0.04	4.71 (1.41-15.76)	0.01
Postop. center-edge angle of <30° or >40°	5.24 (1.18-23.26)	0.03	4.37 (0.98-19.56)	0.05
Preop. fovea-acetabular angle of < −11°	3.48 (1.05-11.57)	0.04	2.30 (0.64-8.29)	0.20
Postop. acetabular sclerotic zone width of <2.5 cm	5.10 (1.44-18.10)	0.01	6.17 (1.68-22.67)	0.006
Postop. distance X of ≥ 2.0 cm	5.23 (1.79-15.32)	0.003	4.44 (1.50-13.09)	0.007
Postop. distance Y of ≥10.8 cm	4.38 (1.55-12.34)	0.005	4.64 (1.65-13.04)	0.004
Postop. roundness index of >0.68	5.07 (1.43-17.98)	0.01	3.53 (0.96-13.00)	0.06
Preop. evidence of os acetabuli	4.88 (1.66-14.34)	0.004	3.60 (1.17-11.09)	0.03
Postop. evidence of os acetabuli	3.34 (1.06-10.51)	0.04	2.38 (0.73-7.80)	0.15
Preop. minimal joint space width of <3.0 mm	3.97 (1.26-12.48)	0.02	1.72 (0.40-7.35)	0.47
Postop. minimal joint space width of <3.0 mm	5.85 (2.08-16.47)	0.001	3.45 (0.70-17.08)	0.13
Preop. Tönnis grade 2 or 3	5.54 (1.89-16.24)	0.002	NA	
Postop. Tönnis grade 2 or 3	5.73 (1.96-16.78)	0.001	NA	
Computed tomographic data				
Coronal center-edge angle of <5°	5.20 (1.94-13.90)	0.001	4.40 (1.54-12.53)	0.006
Acetabular anteversion angle of <10°	6.79 (2.18-21.09)	0.001	4.29 (1.13-16.28)	0.03

*The crude hazard ratios were adjusted for the preoperative grade of osteoarthritis according to the Tönnis classification system. NA = not adjusted.

Results

Study Group Characteristics and Survival Analysis

As a result of the acetabular reorientation, the preoperative median center-edge angle of 11° (interquartile range, 5° to 19°) and acetabular index angle of 20° (interquartile range, 14° to 28°) changed to median postoperative values of 29° (interquartile range, 23° to 34°) and 8° (interquartile range, 0° to 12°), respectively. In 90% of the procedures (100 procedures in eighty-four patients), the preoperative Tönnis grade of osteoarthritis was 0 or 1. Ten percent (eleven procedures in ten patients) had grade 2, and none had grade 3 (Table I). The values of other preoperative and postoperative radiographic parameters are presented in Table I. Of the 116 procedures in ninety-six patients, seventeen in sixteen patients were converted to total hip replacement within the mean follow-up period of 6.8 years (range, 5.2 to 9.2 years). With conversion to total hip replacement as the end point, the Kaplan-Meier analysis showed a survival rate of the hip of 90.5% (95% confidence interval, 83.5% to 94.6%) at five years and 81.6% (95% confidence interval, 69.7% to 89.3%) at 9.2 years (Fig. 4).

Results of Follow-up

At the time of follow-up, the median pain score on the visual analog scale was 0 (interquartile range, 0 to 1) at rest and 1 (interquartile range, 0 to 3) after fifteen minutes of normal walking. The most common location for hip pain or discomfort was the groin in 34% (twenty-six) of seventy-seven hips, and the impingement test was positive in 18% (fourteen) of seventy-seven hips (Table II). These results and others from the interview and examination at the time of follow-up are presented in Table II. The median physical component score on the SF-36 was 48.31 (interquartile range, 39.34 to 54.65), and the median mental component score on the SF-36 was 57.95 (interquartile range, 51.39 to 61.07). The median WOMAC total score was 84.44 (interquartile range, 70.20 to 95.83). At the time of follow-up, the crossover sign was seen in 26% (twenty) of seventy-six hips upon the assessment of weight-bearing pelvic radiographs. The Tönnis grade of osteoarthritis was 0 or 1 in 82% (sixty-two) of seventy-six hips, grade 2 in 10% (eight hips), and grade 3 in 8% (six hips) (Table II). The presence of a crossover sign on weight-bearing pelvic radiographs at the time of follow-up could not be identified as a significant predictor of the development of Tönnis grades 2 or 3 at the time of follow-up.

Predictors of Conversion to Total Hip Replacement

Analysis of possible predictors of conversion to total hip replacement identified sixteen demographic and radiographic (conventional and computed tomographic) factors that had a crude hazard ratio significantly different from a value of 1.0 (Table III). The crude hazard ratios were adjusted for the Tönnis

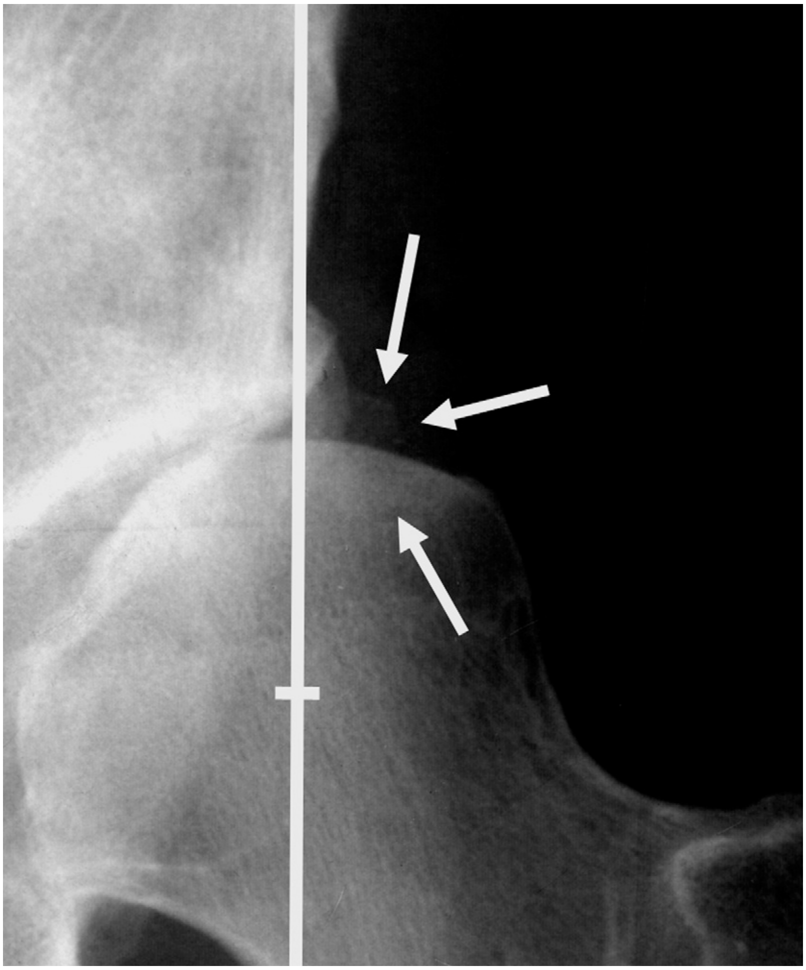

Fig. 5

Severe dysplasia and os acetabuli. The vertical line through the center of the femoral head runs through the most lateral limit of the sclerotic acetabular roof, indicating a center-edge angle of 0°. The os acetabuli at the lateral acetabular margin is marked by arrows.

grade of preoperative osteoarthritis, leaving seven factors with adjusted hazard ratios significantly different from a value of 1.0: (1) the preoperative center-edge angle of <0°, with a hazard ratio of 4.71 (95% confidence interval, 1.41 to 15.76) ($p = 0.01$); (2) the postoperative width of the acetabular sclerotic zone of <2.5 cm, with a hazard ratio of 6.17 (95% confidence interval, 1.68 to 22.67) ($p = 0.006$); (3) the postoperative x coordinate of femoral head translation of ≥2.0 cm, with a hazard ratio of 4.44 (95% confidence interval, 1.50 to 13.09) ($p = 0.007$); (4) the postoperative y coordinate of femoral head translation of ≥10.8 cm, with a hazard ratio of 4.64 (95% confidence interval, 1.65 to 13.04) ($p = 0.004$); (5) the preoperative presence of an os acetabuli, with a hazard ratio of 3.60 (95% confidence interval, 1.17 to 11.09) ($p = 0.03$); (6) the coronal center-edge angle of <5° on the computed tomographic scan, with a hazard ratio of 4.40 (95% confidence interval, 1.54 to 12.53) ($p = 0.006$); and (7) the acetabular anteversion angle of <10°, with a hazard ratio of 4.29 (95% confidence interval, 1.13 to 16.28) ($p = 0.03$). The crude hazard ratio for the preoperative Tönnis grades of 2 and 3 as a predictor for conversion to total hip replacement was 5.54 (95% confidence interval, 1.89 to 16.24) ($p = 0.002$) (Table III).

Discussion

Kralj et al.[9] reported conversion to total hip replacement in 15% (four) of twenty-six hips at a mean of twelve years (range, seven to fifteen years) after periacetabular osteotomy. Two studies[3,13] with a mean follow-up of 11.3 years and 20.4 years, respectively, described the outcome of the first seventy-five consecutive hips in the Berne group study. In the recent study, Steppacher et al.[13] described the long-term Kaplan-Meier survivorship rate, which was 87.6% (95% confidence interval, 80.1% to 95.2%) at ten years. This is roughly comparable with our estimate of 81.6% at a follow-up of 9.2 years. Our present study group is comparable with that reported by Steppacher et al.[13], and both studies are reports of the initial experience with periacetabular osteotomy by a single surgeon. At the time of follow-up, 8% (six) of seventy-six preserved hips in the present study had grade-3 osteoarthritis according to the Tönnis classification, which, depending on the associated pain and patient activity level, may have qualified the patients as candidates for total hip arthroplasty.

Not surprisingly, the groin is the most frequent location of hip-related pain or discomfort. The presence of osteoarthritis can explain this, but the sensation of clicking or locking in 25% (nineteen) of the seventy-seven hips and a positive impingement test in 18% (fourteen hips) suggest that intra-articular problems may coexist. Steppacher et al.[13] reported the impingement test was positive in 24% of the hips in their study at a ten-year follow-up evaluation. Acetabular labral tears are frequent in symptomatic dysplastic hips. It remains controversial whether arthrotomy should be performed routinely to address intra-articular pathology. Dysesthesias of the lateral femoral cutaneous nerve were found following 48% (thirty-seven) of our seventy-seven procedures. This is a well-known complication for both the ilioinguinal and the modified Smith-Petersen approaches[30].

Most of the previous studies describing the outcome after periacetabular osteotomy used the Merle d'Aubigné and Postel score or the Harris hip score[3,4,7,8,10,11]. Those scores may not provide an adequate assessment of joint-preserving surgery in young adults, and therefore we assessed the outcome at the time of follow-up using the contemporary SF-36[26] and WOMAC[27] scores. Few studies have previously described measurements of these scores following periacetabular osteotomy[9,31,32], and, because of different strategies of transforming raw WOMAC scores, no reliable comparisons can be made. We found the median WOMAC score and median pain scores on the visual analog scale in the present study to be satisfactory at a medium-term follow-up. In one study, van Bergayk and Garbuz reported a mean physical component score on the SF-36 of 49.2 and a mean mental component score of 54.7 for twenty-two patients with a follow-up of 2.0 to 3.5 years after periacetabular osteotomy[31]. These scores are comparable with the scores that we reported (48.31 and 57.95, respectively) at a mean follow-up of 6.8 years. Normative data for Danish citizens from twenty-five to thirty-four years old are 55.43 (interquartile range, 52.31 to 57.73) for the physical component score and 56.15 (interquartile range, 50.73 to 58.57) for the mental component score[26]. As expected, the physical component score is less, whereas the mental component score in our patients is comparable, suggesting that physical health has no negative influence on the mental quality of life at a medium-term follow-up. It remains a limitation of our study that we have no preoperative scores.

Future improvement in the outcome following periacetabular osteotomy is likely to rely on refinement of the patient selection criteria and on further focus on aspects of acetabular reorientation. Previously, advanced stages of osteoarthritis preoperatively were suggested as a factor negatively influencing survival of the hip[2-4,9,13,14]. We confirmed and quantified an advanced stage of preoperative osteoarthritis (Tönnis grades 2 and 3) as a significant risk factor for conversion to total hip replacement. The possible negative influence on the outcome of demographic, clinical, and radiographic factors was then analyzed, adjusting for the presence of advanced osteoarthritis. Seven significant risk factors of conversion to total hip replacement were identified (Table III). Given the study sample size and the applied statistical method, it should be made clear that this analysis is merely a suggestion of what to focus on in the future assessment of candidates for periacetabular osteotomy. The results need to be confirmed in larger studies.

Overload and possible shearing impingement is thought to cause tearing of the labrum and damage to the acetabular rim identified as a so-called os acetabuli[21,22,24] (Fig. 5). The identification of an os acetabuli as a significant risk factor is not surprising. Very low center-edge angles and reduced acetabular anteversion both represent a markedly abnormal biomechanical environment of the hip. These cases are challenging in terms of achieving proper acetabular reorientation, which may be the reason why these factors were identified as significant predictors of failure.

Postoperative radiographic parameters that predicted a poor outcome include excessive x and y coordinates (proximal and lateral dislocation of the femoral head) and a width of the acetabular sclerotic zone of <2.5 cm. These three parameters identify hips that are prone to overload of the acetabular rim, leading to joint deterioration.

A postoperative center-edge angle from 30° to 40° and an acetabular index angle from 0° to 10° are among the surgical aims of periacetabular osteotomy at our institution. A postoperative center-edge angle of >40° showed an increased risk of failure in the calculation of the crude hazard ratio. Of the risk factors for failure besides preoperative osteoarthritis, which was recently identified by Steppacher et al.[13], we analyzed age at the time of surgery; however, we did not find a significantly increased risk associated with advanced age at the time of surgery when adjusted for the preoperative degree of osteoarthritis.

In the present study, we demonstrated that periacetabular osteotomy can be performed with a satisfactory survival rate of the hip at a medium-term follow-up. The hips that were not converted to total hip arthroplasty were associated with good clinical results, low pain levels, and a good health-related quality of life. An increased focus should be on the potential negative influence of specific parameters, such as the preoperative grade of osteoarthritis, the presence of an os acetabuli, and severe acetabular dysplasia. ■

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