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ORIGINAL ARTICLE

Clinical and radiological outcome after periacetabular osteotomy: a cross-sectional study of 127 hips operated on from 1999-2008

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Purpose: *Few papers have described results after periacetabular osteotomy (PAO) and risk factors for conversion to total hip arthroplasty (THA). The aim of the present paper was to analyse clinical and radiographic outcome, survival of the hip joint and risk factors of early conversion to THA in patients with PAO.*
Basic Procedures: *In the period 1999-2008, 93 patients (127 hips, median patient age 31, range 13-49 years) were operated on with PAO. Median follow-up was 7 (SD 2.1) years. Analyses of clinical and radiographic examinations, including WOMAC, were performed. Osteoarthritis was measured using Tönnis grade. Survival was assessed by the Kaplan-Meier method and predictors of conversion to THA were calculated using Cox regression analysis with THA as defined endpoint.*
Main Findings: *Centre-edge angle improved significantly with a mean of 8.7 (95% CI: 7.1; 10.3) preoperatively to a mean of 24.6 (95% CI: 22.6; 26.6) at follow-up. Likewise the acetabular roof obliquity angle improved significantly with a mean of 21.2 (95% CI: 19.7; 22.6) preoperatively to 8.7 (95% CI: 7.1; 10.4) at follow-up. Eleven out of 127 hips had conversion to THA. The 11.7 years cumulated hip joint survival rate was 85% (95% CI: 0.753; 0.945). Significant predictors of converting to THA were preoperative high grade of OA and postoperative high degree of acetabular roof obliquity angle. An improvement was found in Harris Hip Score pain score after receiving a PAO (p = 0.01).*
The Principal Conclusions: *Our results, with almost 12 years survival data, are comparable with the literature. PAO is considered as an effective treatment for young adults with painful hip dysplasia. Especially when preoperative criteria for conversion to THA are highlighted.*

Keywords: *Hip, Periacetabular osteotomy, Bernese osteotomy, Kaplan-Meier, Regression*

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INTRODUCTION

Periacetabular osteotomy (PAO) described by Ganz et al (1) is a treatment used worldwide among young adults suffering from symptomatic hip dysplasia (HD) (2-4). The consequences of HD are instability of the hip, joint incongruity, abductor insufficiency, limb-length inequality, osteoarthritis (OA) and pain (5-7). In Denmark, the prevalence of radiographic HD is approximately 5.5% (8).

PAO is an operation mainly for patients <50 years suffering from HD (1). The candidates are defined by centre-edge (CE) angle ≤20° and none or only slightly OA (Tönnis grade 0 or 1), symmetry in abduction and acetabular roof obliquity (AA angle) more than 10°(8). The primary goal for the treatment is to seek normalised anatomical conditions, to prevent development of secondary OA, reduce pain and increase the functional level of the hip. PAO patients are normally from 16-60 years old and otherwise healthy (1, 2). PAO has been performed at our institution since 1999 and current improvements have resulted in decreased hospitalisation and changes in length of incision. The literature has identified many variables predicting PAO conversion to total hip arthroplasty (THA) (2, 3, 9-15) and patient selection is crucial for a favourable outcome.

The main aim for this study was to estimate the clinical outcomes of PAO performed at our institution from 1999 to 2008. A secondary aim was to identify demographic, clinical and radiographic parameters as risk factors for PAO conversion to THA.

PATIENTS AND METHODS

The study was designed as a retrospective study including patients who received treatment with PAO at the Department of Orthopaedic Surgery from 1999-2008. The study presents clinical cross-sectional measurements performed at follow-up.

A total of 93 patients (127 hips M/F: 23/104. 25% bilateral) with a mean age of 30 years (SD10.4) (Tab. I) were identified from the diagnosis code system ICD-10 in the Danish Health and Medicine Authority and the Danish Hip Arthroplasty Register.

Patients who met the endpoint criteria (PAO conversion to THA) were identified by the diagnosis code KNFB 20, 30 and 40 in the Danish Hip Arthroplasty Register, and their files were assessed for data/variables at the time of periacetabular osteotomy.

Seventy-five unrevised patients (106 hips) had clinical examination, 70 (99 hips) radiographic examination and 78 (111 hips) answered questionnaires. The examination was done for the purpose of maintaining the high specialised function of PAO and were therefore not a part of the routine follow-up. Radiographs for the patients who underwent conversion to THA were analysed (10 patients/ 10 hips). Patients in pregnancy were not radiographed if date of delivery was after May 7th 2012 (study-deadline). One patient refused to have radiographs taken, and is therefore in the analysis grouped with the pregnant women. Patients having clinical and radiographic examination in 2011 were asked to complete questionnaires by mail, and their records were retrospectively reviewed for data by the surgeon and the two main investigators. In total four patients were lost to follow-up; one had died for unrelated courses, two had emigrated and one refused to participate. We assessed the files of these patients in the Danish Health and Medicine Authority and the Danish Hip Arthroplasty Register and none of the five patients had converted to THA at time of follow-up (see flowchart, Figure 1). The surgeon and the two main investigators performed clinical examinations of all the patients not converted from PAO to THA, from January 15th 2012 to May 7th 2012. This leaves a mean follow-up of seven years (SD 2.1).

Demographic data, clinical outcome and radiographic findings of the included patients are described in Table I below. Furthermore, data is divided into subgroups in two different ways. Split one; data divided into PAO versus THA in order to investigate differences between the groups and to predict conversion to THA. Split two; data divided into Group 0 (operated before November 2004) versus Group 1 (operated after November 2004) in order to describe a learning curve.

Measurements

At follow-up the patients were asked to complete a self-reported questionnaire of the latest Danish version of WOMAC LK 3.1 from 1996 (16), and EQ-5D from 1990 (17). EQ-5D was found useful because of its shortness and assessment of quality of life and daily living. Furthermore, satisfaction of surgery was measured from four satisfactory levels (18). Records were reviewed for: age at operation; gender; BMI (kg/height (m)^2); smoking; duration of surgery; primary disease; left or right hip; duration of hospitalisation. Duration of surgery was measured from the start of skin incision to completion of skin closure (skin-to-skin) (Tab. I).

A guideline was constructed by the two main investigators for the surgeon to follow during the examinations of the patients. This guideline included comorbidity, reoperation, and complications after PAO to make sure that any relevant data of interest after discharge were captured. Furthermore, the length of both legs and degrees of extension, flexion, abduction, adduction, internal/external rotation and positive impingement were recorded. Patients were asked to perform Trendelenburg Test for 30 seconds. The

TABLE I - BASELINE DATA IN TOTAL AND DATA DIVIDED INTO PAO OR THA, AND PATIENTS OPERATED BEFORE NOVEMBER 2004 AND AFTER NOVEMBER 2004

Variables	Presented as	Total population (n = 127)	PAO (n = 116)	Conversion to THA (n = 11)	P-value	Group 0 (n = 62)	Group 1 (n = 65)	P-value
Time of follow up (Years)	mean(SD)	6.7 (SD3.2) (n = 122)	7 (SD2.1) (n = 111)	4.5 (SD3.1) (n = 11)	P = 0.023†*	8.5 (SD1.7) (n = 59)	5.1 (SD1.4) (n = 63)	P<0.001†*
Age at operation (years)	mean(SD)	30 (SD10.4) (n = 127)	30 (SD10.7) (n = 116)	31 (SD9) (n = 11)	P = 0.870†	29 (SD10.7) (n = 62)	32 (SD10.1) (n = 65)	P = 0.185†
Gender (Male/Female)	% men	18.1 (n = 127)	17.2 (n = 116)	27.3 (n = 11)	P = 0.409‡	14.3 (n = 62)	21.5 (n = 65)	P = 0.304‡
BMI(kg/m²)	mean(SD)	23 (SD3.7) (n = 125)	23 (SD3.8) (n = 114)	23 (SD2.8) (n = 11)	P = 0.997†	23 (SD3.6) (n = 60)	24 (SD3.7) (n = 65)	P = 0.731†
Smoking	% of smokers	28.4 (n = 127)	27.6 (n = 116)	36.7 (n = 11)	P = 0-537‡	30.7 (n = 62)	26.2 (n = 65)	P = 0.575‡
Primary disease:								
Congenit acetabular dysplasy	% of total	83.5 (n = 127)	81.9 (n = 116)	100 (n = 11)	P = 0.303‡	88.7 (n = 62)	83.5 (n = 65)	P = 0.279‡
Calve perthes segv.	% of total	3.2 (n = 127)	3.5 (n = 116)	0		1.6 (n = 62)	3.2 (n = 65)	
Cognenit hip lux	% of total	13.4 (n = 127)	14.7 (n = 116)	0		9.7 (n = 62)	16.9 (n = 65)	
Side of operation (Right/Left)	% of right	61.4 (n = 127)	60.3 (n = 116)	72.7 (n = 11)	P = 0.420‡	69.4 (n = 62)	53.6 (n = 65)	P = 0.073‡
Time of surgery (minutes)	mean(SD)	96 (SD30.1) (n = 125)	95 (SD29) (n = 114)	102 (SD41.7) (n = 11)	P = 0.466†	107 (SD32.8) (n = 60)	85 (SD23.1) (n = 65)	P<0.001†*
Before and after november 2004								
Group 0	% of total	48.8 (n = 127)	48.3 (n = 116)	54.6 (n = 11)	P = 0.961‡			
Group 1	% of total	51.2 (n = 127)	51.7 (n = 116)	45.6 (n = 11)				
Duration of hospitalisation (days)	mean(SD)	11 (SD2.8) (n = 127)	11 (SD2.8) (n = 116)	11 (SD2.2) (n = 11)	P = 0.692†	12 (SD2.5) (n = 62)	10 (SD2.9) (n = 65)	P = 0.005†*
Preoperative data								
Tönnis grade								
Grade 0	% of total	61.6 (n = 125)	64 (n = 114)	36.4 (n = 11)	P<0.001‡*	63.3 (n = 60)	60 (n = 65)	P = 0.142‡
Grade 1	% of total	36 (n = 125)	35.1 (n = 114)	45.5 (n = 11)		31.7 (n = 60)	40 (n = 65)	
Grade 2	% of total	2.4 (n = 125)	0.9 (n = 114)	18 (n = 11)		5 (n = 60)	0	
Grade 3	% of total	0	0	0		0	0	
Pre CE angle (degrees)	mean(SD)	9 (SD8.3) (n = 125)	9 (SD8.4) (n = 114)	9 (SD6.5) (n = 11)	P = 0.998†	9 (SD8.7) (n = 60)	8 (SD7.9) (n = 65)	P = 0.791†
Pre AA angle (degrees)	mean(SD)	20 (SD7.4) (n = 112)	21 (SD7) (n = 103)	21 (SD6.4) (n = 9)	P = 0.957†	19 (SD5.7) (n = 47)	22 (SD7.6) (n = 65)	P = 0.089†

† = Independent *t*-test; ‡ = Pearson Chi-Square test; * = Significant.

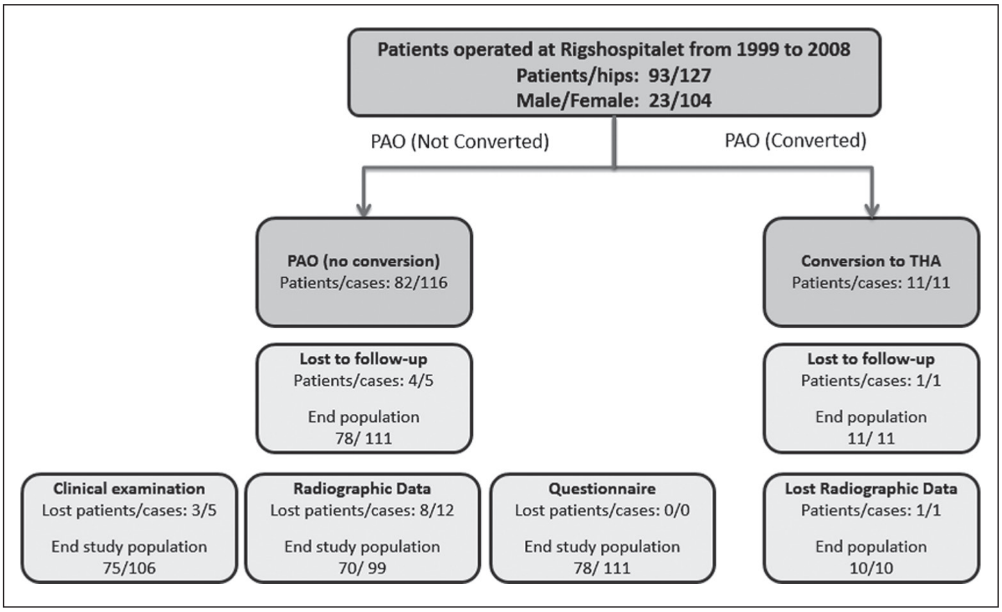

Fig. 1 - *Flowchart of the included patients showing the distribution of clinical exam, radiographs and questionnaires.*

function of the hip was assessed from the latest (January 1st 2004) Danish translated Harris Hip Score (HHS) with a score reaching a maximum of 100 points. HHS was in this study implemented preoperatively in 35 patients (51 hips) and therefore a comparison was possible at follow-up.

Radiographs obtained were frontal pelvis and profile foux in supine position. The location for examination was by one outpatient deemed too far to travel. Therefore the patient had a radiograph taken at the nearest hospital and a telephone interview was completed in addition to the questionnaires. The radiographic measurements included CE angle, AA angle, cross over sign (COS), posterior wall sign (PWS), Shenton line, and Tönnis classification level. The two main investigators performed all radiographic and demographic measurements together using a guideline to ensure reliability. Furthermore the intraobserver reliability for the severity of OA (Tönnis classification level) was evaluated by blinded reevaluation with a one month interval.

Surgical technique

The patient was placed on a radiolucent table in the operating theatre in supine position. A 10 cm incision from just behind the anterior superior spine directed in line with the iliac crest and the ilioinguinal ligament was performed. The fascia was incised just below the ligament and the lateral cutaneous nerve of the thigh was identified. The tip of the anterior superior spine with the ligament attachments was removed with a chisels and held aside. The iliac bone was exposed on the inside and the superior ramus of the iliac bone freed. An osteotomy was performed on this bone. The ischial bone was assessed medial from the hip joint with a long bended chisel. The position of the chisel was secured by fluoroscopy. A partial osteotomy was performed leaving the posterior wall intact. The ilium was then assessed first by saw for the osteotomy above the acetabulum, then by chisels behind the acetabulum. This osteotomy and the quadrilateral osteotomy were performed using fluoroscopy. The fragment was released repositioned and fixed with 2-3 Titanium screws. A headless "Acutrak"® screw secures the anterior iliac spine. With time the technique has developed so that the incision length has been shortened from 12-15 cm to 8 cm but the osteotomies remain the same.

Statistical analysis

The collected data was valuated to be non-parametric or parametric from Levenes test. Following data were evaluated distributed non-parametric: Harris Hip Score, WOMAC, and EQ-5D and are presented as median (interquartile range, 25 percentile and 75 percentile). Following data was evaluated distributed parametric: age, BMI, minutes, millilitres, years, days and degrees and are presented with a mean (standard deviation (SD)). A power calculation was used in the HHS sub analysis to estimate the possibility of type 1 and 2 error. Bilateral observations were included as independent observations. Pearson Chi-square analysis was used for categorical data, distributed on a nominal scale. Independent samples *t*-tests were used to compare the mean values in different patients sub groups. To compare preoperative data and data at follow-up of the same patients, a paired *t*-test was used; Wilcoxon test was used if data was non-parametric. Mann-Whitney test was used for non-parametric data distributed on an ordinal scale. One sample *t*-test was used to report 95% confidence interval (95% CI) of the mean. An intraobserver reliability study for the severity of OA (Tönnis classification level) was performed with a one- month interval. The same surgeon performed Tönnis classification twice. These repeated assessment were blinded and were followed by computation of a weighted a kappa test to evaluate the agreement between repeated assessments. A weighted kappa coefficient was used since the Tönnis ratings are ordinal. Kappa coefficients were computed for the original four point Tönnis score weighted, and for a revised Tönnis score (were Grades 0 and 1 were pooled). Cicchetti-Allison weights were used for the weighted kappa coefficient. Kaplan-Meier survival and a learning curve of the hip joint analysis, was calculated with conversion to THA as primary end point and reported with 95% CI. Patients that were lost to follow-up were not included in the Kaplan Meier analyses. A log-rank test was used to calculate the difference in conversion to THA in the two groups. Cox regression analysis was performed in order to predict variables and covariates with use of Hazard Ratio with THA as end point. Cox regression analysis was chosen because of its time-dependent association between possible predictors and time for conversion to THA, and was calculated in univariate and multiple analyses adjusted for gender, age and OA. The analysis was performed using SPSS software version 20 (SPSS, Chicago, Illinois, USA), STATA version 2012 (Data Analysis and statistical software, Texas, USA) and Excel version 2010 (Microsoft, Redmond, Washington, USA). Calculation of 95% confidence intervals (CIs) for the survival data was done in Microsoft Excel 2010 using Greenwood's formula for calculation of standard error. The level of significance was set at a two-tailed p-value <0.05.

Ethics

The study has been registered at the Danish Data protection Agency (journal number: 2007- 58-0015) and at the Region Scientific Ethics Committee of the Region Denmark (journal number: H-2-2011-FSP27).

RESULTS

Clinical outcome

Eleven (9%) of the 122 hips were converted to THA. The converted patients had a mean follow-up of 4.5 (SD 3.1) years. In total the mean time of follow-up was 6.7 (SD 3.2) years (n = 122).

The mean duration of hospitalisation was in total 11 days (SD 2.8). The mean time of surgery was 96 minutes (SD 30.1). At follow-up the prevalence of positive impingement test was 15 out of 106 hips (14%) and three had a positive Trendelenburg test (3%). The total median WOMAC score was 11/96 point (range 2-23) and subscale for pain was 3 points (range 0-6). The total EQ-5D median score was 0.82/1 points (SD 0.72-1). Evaluating the satisfaction score of 111 hips showed that 57 were very satisfied, 33 satisfied, eight less satisfied and 13 were not satisfied.

The median total HHS was 84/100 points (range 71-95) at follow-up (n = 111). An analysis of 51 hips, with preoperative HHS available, indicates a tendency for favorable scores at follow-up (p = 0.09). An improvement at follow-up in pain score (p = 0.02, with a power at 81%) and a decreased score (p = 0.06, with a power at 52%) at follow-up in walking ability was found. The range of motion was similar in both groups (Tab. II).

Intraobserver reliability

Kappa coefficients were computed for the original four point Tönnis score weighted, and for a revised Tönnis score (Grade 0 and 1 were pooled). For the four point Tönnis score the weighted kappa coefficient was 0.49 (95% CI: 0.35; 0.63), and for the revised Tönnis score the weighted kappa coefficient was 0.72 (95% CI: 0.55; 0.88).

Kaplan-Meier survival analysis

The Kaplan-Meier analysis (Fig. 2) suggests that the probability of hip joint survival after 11.7 years was 85% (95% CI: 0.753; 0.945). Five of 11 hips converted to THA within the first three years after PAO surgery, indicating a survival probability of 96% after three years.

TABLE II - HARRIS HIPS SCORE PREOPERATIVELY AND AT FOLLOW-UP (N = 51)

Harris Hip Score	Presented as	Pre-operative	Follow-up	P-value	Power**
Total Score	Median (interquartile range)	83 (72-86) (n = 52)	84 (76-95) (n = 52)	P = 0.086‡	37%
Pain	Median (interquartile range)	30 (20-30)	30 (30-40)	P = 0.017‡*	81 %
Walking ability	Median (interquartile range)	47 (42-47)	44 (36-47)	P = 0.060‡	52 %
Range of motion#	Median (interquartile range)	5 (-)	5 (-)	P = -	%

‡Wilcoxon test; #Everyone had a score of 5; *Significant.
**Calculated using the actual measure difference as the clinically relevant difference, SD of the changes and type 1 error of 5 %.

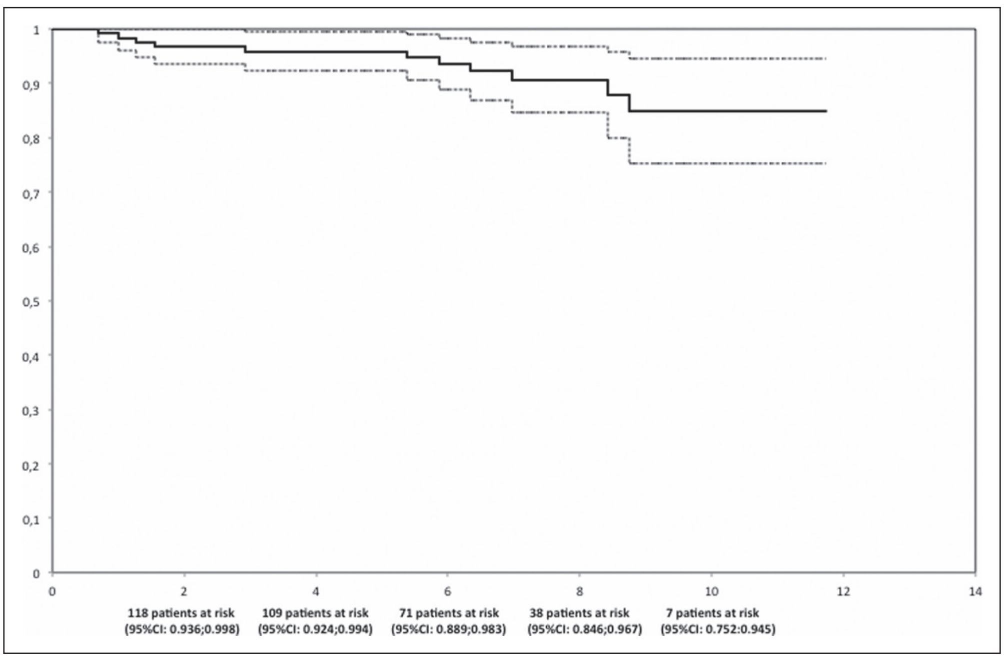

Fig. 2 - *Kaplan-Meier hip joint survival analysis.*

Learning curve

Group 0 (operated before November 2004) and Group 1 (operated after November 2004) were homogeneous at baseline (Tab. I). A significant difference between the groups was seen pre- and postoperatively in duration of surgery, and duration of hospitalisation and time of follow-up, all parameters lower in Group 1. A significant higher degree of OA was found in Group 0 compared to Group 1 (Tab. III). There were no significant differences in total mean satisfaction, WOMAC or EQ-5D. However, in EQ-5D sub scale analysis, Group 1 was significantly more anxious and depressive than Group 0. A Kaplan-Meier learning curve showed no difference in conversion to THA (p = 0.26), but in Group 1 the patients were converted faster to THA (p = 0.04) (Tab. III).

Radiographs

At the time of follow-up, PWS was seen in 66 hips of 109 hips (61%) upon the assessment of front pelvis in supine radiographies. The integrity of Shenton line (>5 mm) was broken in 13 hips (12%), and COS was seen in 11 hips (9%). The severity of osteoarthritis have exacerbated at follow-up (p = 0.01).
CE angle (n = 108) improved significantly from a preoperative mean of 8.7° (95% CI: 7.1°; 10.3°) to a postoperative of 24.6° (95% CI: 22.6°; 26.6°) (p<0.001). Likewise, the mean

TABLE III - OUTCOMES AT FOLLOW-UP

PAO learning curve	Presented as	Group 0 (Before 2004)	Group 1 (After 2004)	P-value
WOMAC at follow-up				
Total - Score	Median (interquartile range)	13 (1-29) (n = 52)	11 (3-18) (n = 52)	P = 0.982§
Pain	Median (interquartile range)	4 (0-7)	2 (1-5)	P = 0.608§
Stiffness	Median (interquartile range)	1 (0-2)	1 (0-2)	P = 0.610§
Function	Median (interquartile range)	7 (1-20)	7 (2-12)	P = 0.769§
EQ-5D at follow-up				
Total - Score|||	Median (interquartile range)	0.82 (0.71-1) (n = 53)	0.82 (0.78-1) (n = 58)	P = 0.324§
Mobility	Median (interquartile range)	1 (1-2)	1 (1-2)	P = 0.947§
Self-care	Median (interquartile range)	1 (1-1)	1 (1-1)	P = 0.292§
Usual activities	Median (interquartile range)	1 (1-2)	1 (1-2)	P = 0.362§
Pain / Discomfort	Median (interquartile range)	2 (1-2)	2 (1-2)	P = 0.918§
Anxiety / Depression	Median (interquartile range)	1 (1-1)	1 (1-1)	P = 0.021§*
Satisfaction at follow-up		n = 53	n = 58	
Very Satisfied	Number	31	26	P = 0.432‡
Statisfied	Number	12	21	
Less Satisfied	Number	4	4	
Unsatisfied	Number	6	7	
Harris Hip Total score points	Mean (SD)	80.6 (SD16.1) (n = 53)	81.3 (SD16.2) (n = 58)	P = 0.815†
Trendelenburg	% for positive	2 (n = 50)	3.6 (n = 56)	P = 0.626‡
Impingement	% for positive	18 (n = 50)	10.7 (n = 56)	P = 0.283‡
Postoperative CE angle	Mean (SD) degrees	23.5° (SD12.1) (n = 51)	25.4° (SD8.8) (n = 58)	P = 0.341†
CE angle delta	Mean change in degrees	15,4	16.4	P = 0.629||
Postoperative AA angle	Mean (SD) degrees	9.4° (SD8.9) (n = 51)	8.9° (SD7.4) (n = 58)	P = 0.739†
AA angle delta mean (change)	Mean change in degrees	11.9	12.8	P = 0.561||
Acetabular retroversion	% for positive	28 (n = 51)	41 (n = 58)	P = 0.088‡
Postoperativ Tönnis	Median (interquartile range)	1 (0-1) (n = 46)	0 (0-1) (n = 53)	P = 0.046§*

† = Independent *t*-test ‡ = Pearson Chi-Square test; § = Mann-Whitney test; * = Significant; || = Two sample *t* test; ||| = Calculated from STATA.

AA angle (n = 94) improved from 21.2° (95% CI: 19.7°; 22.6°) preoperatively to 8.7° (95% CI: 7.1°; 10.4°) at follow-up (p<0.001).

Regression analysis

Analysis of possible predictors of conversion to THA identified two radiographic factors as being significantly different from one. The preoperative Tönnis grade 2 revealed a hazard ratio of 15.02 (95% CI; 2.73: 82.85) for converting to THA compared to Tönnis grade 0. Furthermore, postoperative increased AA angle was a significant predictor for THA with a hazard ratio of 1.08 (95% CI; 1.02: 1.05). When adjusted for age, gender and OA no other risk factors for conversion to THA occurred (Tab. IV).

Complications

Minor complications occurred in 86 hips: damage to the lateral cutaneous nerve of the thigh was found in 80 hips, two urinary tract infections (treated with antibiotics for six days), one patient was oozing from the cicatrices (antibiotics for additional two days), one delayed healing of ramus superior (did not require any surgery). Major complications

TABLE IV - COX REGRESSION ANALYSIS

Cox Proportional Hazard Model	Univariate analysis		Multible analysis		Multible analysis		Univariate analysis		Reference
Endpoint	**THA**		**THA**		**THA**		**THA and WOMAC pain score <10**		
Adjusted for			**Age and gender**		**OA**				
(n = 127)	**Hazard ratio (95% CI)**	**P-value**	**Hazard ratio (95% CI)**	**P-value**	**Hazard ratio (95% CI)**	**P-value**	**Hazard ratio (95% CI)**	**P-value**	
Demographics									
Age at operation	1.01 (0.96; 1.07)	P = 0.709	n/a	n/a	0.99 (0.93; 1.05)	P = 0.683	0.99 (0.95;1.04)	P = 0.773	Per one year older
Gender	2.01 (0.53; 7.59)	P = 0.305	n/a	n/a	1.42 (0.35; 5.71)	P = 0.623	1.99 (0.06;6.13)	P = 0.227	Women
BMI	1.01 (0.86; 1.18)	P = 0.941	0.96 (0.78; 1.18)	P = 0.702	1.03 (0.88; 1.21)	P = 0.695	1.03 (0.91;1.16)	P = 0.662	Per one increased point
Smoking	1.25 (0.36; 4.28)	P = 0.276	1.54 (0.31;7.62)	P = 0.595	0.89 (0.24; 3.34)	P = 0.866	0.28 (0.06;1.20)	P = 0.086	Non - smokers
After 2004	2.23 (0.54; 9.19)	P = 0.269	2.06 (0.49; 8.57)	P = 0.322	3.27 (0.71; 15.13)	P = 0.129	28.95 (3.49;239.8)	P = 0.002*	Before 2004
Clinical									
Primary disease									
Congenit hip luxation	0.04 (0.00; 102.83)	P = 0.419	n/a	n/a	n/a	n/a	1.83 (0.61;5.52)	P = 0.285	Congenit acetabular HD
Calve- Perthes Seqv.	0.04 (0.00; 1512094)	P = 0.715	n/a	n/a	n/a	n/a	0.00 (0.00;0.00)	P = 0.984	Congenit acetabular HD
Radiographic									
Preoperative Tonnis Grade									
Grade 1	2.45 (0.66; 9.16)	P = 0.183	2.27 (0.58; 8.93)	P = 0.241	n/a	n/a	1,46 (0.56; 3.79)	P = 0.44	Reference Grade 0
Grade 2	15.02 (2.73; 82.85)	P = 0.002*	17.46 (2.69; 113.58)	P = 0.003*	n/a	n/a	11.24 (1.34; 94.34)	P = 0.026*	Reference Grade 0
Preoparative CE angle	1.01 (0.94; 1.08)	P = 0.877	0.99 (0.93; 1.08)	P = ’0.990	1.03 (0.95; 1.11)	P = 0.531	1.04 (0.98; 1.10)	P = 0.251	Per one increased degree
Preoperative AA angle	0.99 (0.91; 1.10)	P = 0.965	0.99 (0.89; 1.09)	P = 0.809	0.97 (0.87; 1.09)	P = 0.628	0.98 (0.91; 1.05)	P = 0.497	Per one increased degree
Shentons line	1.13 (0.17; 10.54)	P = 0.785	1.43 (0.18; 11.57)	P = 0.738	1.11 (0.14; 9.09)	P = 0.925	0.86 (0.19; 1.08)	P = 0.845	Integrery of Sheltons line
Postoperative CE angle	0.96 (0.92; 1.01)	P = 0.092	0.95 (0.90; 1.00)	P = 0.059	0.96 (0.91; 1.01)	P = 0.083	1.03 (0.98; 1.08)	P = 0.211	Per one increased degree
Postoperative AA angel	1.08 (1.01; 1.15)	P = 0.008*	1.12 (1.04; 1.20)	P = 0.004*	1.09 (1.02; 1.16)	P = 0.015*	0.96 (0.90;1.03)	P = 0.298	Per one increased degree
Acetabular retroversion	1.59 (0.41; 6.19)	P = 0.506	1.53 (0.39; 5.10)	P = 0.541	1.05 (0.25; 4.34)	P = 0.95	1.61 (0.56; 4.68)	P = 0.38	Non retroverted

*significant.

occurred in nine hips: two peroneal nerve palsies (one was transient and one demanding permanent use of brace), one transient reflex sympathetic dystrophy, two revision of broken trochanter following trochanter distalisation, two deep venous trombe, one intra-articular osteotomy (where the reduction of acetabulum was aborted, and reoperation was not performed with regard to the patient's request), two pseudoarthroses requiring reoperation of the ramus superior with subsequent healing. Twenty hips had additional subsequent surgery: 16 screw removal, three revisions of PAO and one tenorafia rectus femoris.

DISCUSSION

We found that 11/122 hips were converted to THA (9%) after 6.7 years. Kralj et al (12) reported PAO conversions to THA in 4/26 hips at a mean of 12 years after PAO. Troelsen et al (19) reported 17 PAO conversions to THA out of 116 hips at a follow-up of 6.8 years, and Matheney et al (3) also reported 17 PAO conversions to THA of 135 hips at a mean follow-up of nine years. This paper has a reduced number of PAO conversions to THA compared to the described literature. The reduced number of PAO conversion to THA can emerge because the above-mentioned studies have operated an increased sample with preoperative Tönnis grade 2. Our results indicate that the surgeon has only selected patients with preoperative Tönnis grade <2 in Group 1 compared to Group 0 (Tab, I). This could be the reason why this present study has a lower amount of PAO conversions to THA compared to Troelsen et al (2009) who found 10% and Matheney et al (2010) who found 19% with preoperative Tönnis grade ≥2.

The total mean duration of hospitalisation (11 days) in this study is comparable to the study of Pogliami et al (20) who report 7-10 days. The duration of hospitalisation in this study is higher than reported by Troelsen et al (11) (eight days). They reported the length of hospitalisation in patients operated in the second half of their learning curve. In our study the length of hospitalisation in the second half of the learning curve (Group 1) is 10 days. In the present study, one patient had a length of hospitalisation of 26 days and considering this patient an outlier could explain the difference in the mean lengths of hospitalisation.

In the present study the mean total time of surgery was 96 minutes. This is lower compared to previous papers reporting a mean duration of surgery of 120 minutes, and a range from 144 to 348 minutes, respectively (21, 22).

In this study 14% patients had positive impingement test. Steppacher et al (2) and Troelsen et al (23), report 32% and 18% respectively with impingement, which is slightly more pronounced than this study. The impingement phenomenon is caused by surgical difficulties between the balance of under-correction and over-correction of the acetabular fragment and to restore correct anteversion.

In this study 2.8% (three patients) had a positive Trendelenburg test. Nunley et al (24) report of this study group that 48% were associated with a limp and of these 97% had positive impingement sign, and 38% had positive Trendelenburg test.

The outcome of the hip function, satisfaction and pain at follow-up were assessed using WOMAC, level of satisfaction, EQ-5D and HHS. We found a median WOMAC score of 11 points which is lower than Biedermann et al (25), who reported a mean WOMAC score of 25.1 points at 7.4 years of follow-up. In a subscale of WOMAC, a pain score with a median of 3 was found at follow-up, which is comparable to Matherney et al (3) and Millis et al (26). Several different strategies in transforming the raw WOMAC scores exist (27, 28), and therefore not many reliable comparisons can be made.

No studies measured quality of life using EQ-5D at follow-up. In this study the EQ-5D total median score was 0.82. Sørensen et al (29) report normative data from Danish citizens (22-29 years old) showing a mean score of 0.93. In our study 90 patients of 111 were very satisfied or satisfied at follow-up. The level of satisfaction in our study is considered favourable even though we did not find any previous studies measuring satisfaction in four levels.

In this paper a total HHS median of 84 were found, and this is according to Harris (30) equal to a good hip function. Comparable results are also seen in literature (4, 6, 15, 26, 31). There was no significant improvement in HHS between preoperative and values at follow-up (p = 0.09). Other studies (4, 6) reported a significant improvement in the total score. The difference in the total scores may be due to a small sample size and the lack of sensitivity in the measurement of range of motion. However, a significant clinical improvement in HHS pain was found, likewise Ito et al (4).

As expected a significant improvement in preoperative CE and AA angle was found at follow-up similar to results from the literature (2, 3, 5, 11-13, 22, 32). We observed a significant progression of osteoarthritis in the PAO population from preoperative to follow-up (p = 0.005). Steppacher et al (2) did not find the same progression in osteoarthritis after follow-up of 10 years, but did after 20 years. These results may be an expression of the progression of osteoarthritis over time and the observer variability in measuring the grades.

In the present study the probability of survival of the hip joint was 85% after 11.7 years of follow-up. Troelsen et al (11) found a Kaplan-Meier survival rate of 81% (9.2 years of follow-up), Matherney et al (3) 84% (10 years of follow-up), Steppacher et al (2) 88% (10 years of follow-up) and 61% (20 years of follow-up), Kralj et al (12) 85% (12 years of follow-up), Siebenrock et al (9) 82% (11.3 years of follow-up). These studies all had THA as primary endpoint. The result of our study is comparable to the literature.

The learning curve, expressed as difference between Group 0 and Group 1 in our paper, suggesting a significant improvement in postoperative Tönnis (p = 0.05), which can be a result of the differences in time of follow-up (Tab. III). The proficiency demonstrated in the learning curve is showing a reduced time of surgery (p<0.001) (Tab. I). Furthermore, significance was found in length of hospitalisation (p = 0.01). Previous papers also find significant improvement in mentioned variable in their learning curve (10, 22, 33-35).

The postoperative frequency of posterior wall sign is 61% in this paper. The literature reports acetabular retroversion in the dysplastic hip from 15-42% (31, 36-38). A comparison between studies is problematic because of unequal definitions of acetabular retroversion. This paper use the definition by Werner et al (39). This definition is the newest in the literature and describes the appearance of posterior wall sign as acetabular retroversion. Steppacher et al (2) discovered at follow-up 70% with posterior wall sign, which are similar to our findings and definition of acetabular retroversion. Some papers define acetabular retroversion as the presence of crossover sign only (4, 22), which in this study is 9%. The difference in definitions can explain the reduced percentages of acetabular retroversion compared to this paper.

Previous papers indicate a correlation between acetabular retroversion and the appearance of impingement (2). The prevalence of positive impingement in this study was 14% and does not reflect the prevalence of acetabular retroversion of 61%. The large difference between the radiographic sign of retroversion and the clinical sign of impingement can be ascribed to the general flattening of acetabulum in dysplasia so that retroversion not necessarily results in clinical impingement.

The results of the regression analysis indicate, that the presence of preoperative Tönnis grade 2 in the dysplastic hip increases the risk of PAO conversion to THA by 15 times compared to Tönnis grade 0 in this paper (Tab. IV). Another significant factor for PAO conversion to THA is increased AA angle postoperatively. Every time the postoperative AA angle increases, the risk for conversion rises with a Hazard Ratio of 1.08. When adjusted for age, gender and osteoarthritis the risk factors remain significant. This is similar to previous studies (2-6, 9, 11-13, 26, 31, 40, 41).

Damage to the lateral nervous cutaneous of the thigh is frequent (n = 80) with this kind of surgery and must be considered as a side effect of the surgery rather than a complication. A significant and long learning curve has been reported in previous papers (25). PAO is a technically demanding procedure with a relatively high complication rate (1, 42). Our findings are similar to the literature.

The limitations of the present study include the lack of preoperative data of WOMAC and EQ-5D score. Only limited number of the preoperative HHS was available, and the surgeon preoperatively filled in the measurements in contrast to the data that was self-reported at follow-up. A risk for desirability bias may therefore occur. We have experienced that some patients have difficulties in isolating their self-reported scores to only the operated hip and these difficulties may lead to reporting bias. The variables were drawn into histograms and a subjective assessment decided if data was distributed normally. This may lead to misjudgment in some of the variables. Many p-values were calculated because of the large amount of variables in this study. It is obvious, that performing a large number of statistical tests increases the risk of Type I error. For this reason the regression analysis only considers tests for variables based on the literature. This may reduce the inherent multiple testing problems. The limited number of patients converted to THA limits the statistical power of this study, and this concern is similar to other studies (2, 23, 43). The retrospective design of this study is performed over a learning curve and therefore our clinical results, conversion rate and complications can be more favourable in the future.

The strengths of this study are several. We included a relatively large sample size with a long-time of follow-up. The response rate is high with only four patients (five hips) lost to follow-up in comparison to previous studies (5, 10-12). Furthermore, the two main investigators evaluated all radiographic measurements together, leading to an improvement of the validity. A blinded observer would have been preferred, but the risk of measurement bias will always be present. We also performed a computed a weighted kappa coefficient in order to make the difficulties in the classification of Tönnis visible. The Danish Hip Arthroplasty Register is a reliable register. Therefore, we are certain to locate PAO patients with conversion to THA despite they are lost to follow-up. Though, there will always be a risk in retrospective studies of register bias and an uncertainty of diagnostic codes.

In conclusion the clinical outcomes and radiographic measurements of the PAO hips that were not converted to THA, were associated with good clinical results as a low pain level and good health related quality of life. The outcome of the present study is comparable to the literature. The analysis demonstrates that PAO is performed with a survival probability of the hip joint of 85% after 11.7 years. The identified independent predictors for PAO conversion to THA are preoperative Tönnis grade more than 1, and per one increased AA angle degree postoperatively the risk for PAO conversion to THA increases. After adjustment for age, gender and OA significance is still present.

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