HIP

Minimally invasive periacetabular osteotomy using a modified Smith-Petersen approach

TECHNIQUE AND EARLY OUTCOMES

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Aims

Periacetabular osteotomy is an effective way of treating symptomatic hip dysplasia. We describe a new minimally invasive technique using a modification of the Smith-Petersen approach.

We performed a prospective, longitudinal cohort study to assess for any compromise in acetabular correction when using this approach, and to see if the procedure would have a higher complication rate than that quoted in the literature for other approaches. We also assessed for any improvement in functional outcome.

Patients and Methods

From 168 consecutive patients (189 hips) who underwent acetabular correction between March 2010 and March 2013 we excluded those who had undergone previous pelvic surgery for DDH and those being treated for acetabular retroversion. The remaining 151 patients (15 men, 136 women) (166 hips) had a mean age of 32 years (15 to 56) and the mean duration of follow-up was 2.8 years (1.2 to 4.5). In all 90% of cases were Tönnis grade 0 or 1. Functional outcomes were assessed using the Non Arthritic Hip Score (NAHS), University of California, Los Angeles (UCLA) and Tegner activity scores.

Results

The mean pre-operative lateral centre-edge angle was 14.2° (-5° to 30°) and the mean acetabular index was 18.4° (4° to 40°). Post-operatively these were 31° (18° to 46°) and 3° (-7° to 29°), respectively, a significant improvement in both (p < 0.001). Allogenic blood transfusion was required in two patients (1.2%). There were no major nerve or vascular complications, and no wound infections. At the time of last follow-up, we noted a significant improvement in functional outcome scores: UCLA improved by 2.31 points, Tegner improved by 1.08 points, and the NAHS improved by 25.4 points (p < 0.001 for each). Hypermobility and longer duration of surgery were significant negative predictors for a good post-operative UCLA score, while residual retroversion was a positive predictor of post-operative UCLA score.

Conclusion

We have found this approach to be safe and effective, facilitating early recovery from surgery.

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Periacetabular osteotomy (PAO) has been established as an effective technique in the management of symptomatic hip dysplasia.1-3 The aim of the surgery is to perform a three-dimensional re-orientation of the acetabulum to provide better coverage of the femoral head. This biomechanical change is intended to alter the mechanical loading of the articular cartilage, which in turn alters the composition of the cartilage matrix with consequent delay in the onset of secondary osteoarthritis.4 Good long-term results have been described by a number of authors in different institutions, and there are reasonable data to suggest that a delay in the need for hip replacement in this relatively young group of patients is obtained, in addition to improving pain, function and activity in the medium to long term.5-13

The surgical technique has evolved with the aim of reducing the risks of notable complications that can adversely affect the outcome.14,15 Several approaches have been described with some studies suggesting that the modified Smith-Petersen approach may be the better in terms of blood loss and complication rate than the ilioinguinal and two incision...
Smith-Peterson approach.16 A minimally invasive approach has been developed with the aim of not only achieving a cosmetically pleasing scar, but also to reduce soft-tissue dissection with reduced blood loss during surgery, earlier discharge from hospital and quicker rehabilitation.17 Clearly any such approach should not compromise the adequacy of correction, the functional outcome and complication rate.

The senior author (JDW) has developed a minimally invasive surgery (MIS) technique for PAO, which represents a modification of the Smith-Peterson approach. In addition to the benefit of the MIS approach it also protects the lateral cutaneous nerve (LFCN) of the thigh. The technique was developed by making incremental changes to the original approach over a period of one to two years during which time approximately 70 PAOs were undertaken. The final change was to the position and direction of the skin incision. This paper is a description of the final iteration of this new approach and presents the early results.

The aim is to assess if any compromise in the acetabular correction resulted from this approach, and to ensure that the procedure does not have a higher complication rate than that quoted in the literature for other approaches to acetabular correction. We also investigated whether there was an improvement in functional outcome following surgery.

Patients and Methods
We performed a prospective longitudinal cohort study of patients undergoing MIS PAO surgery using this new surgical technique developed by the senior author (JDW). Between March 2010 and March 2013, 189 hips (174 from women, 15 from men) in 168 patients, underwent MIS PAO surgery using this technique. 17 patients operated on for acetabular retroversion (23 hips) were excluded for the purposes of this study as the radiographic indices have significantly different values when making an assessment of correction for dysplasia.18 This left 166 hips (151 patients; 15 men, 136 women) to be included in the analysis. The mean age of patients at the time of surgery was 32 years (15 to 56). The mean follow-up was 2.8 years (1.2 to 4.5).

All procedures were performed by the senior author (JDW). The senior author had performed more than 200 PAOs using the standard extensile modified Smith-Peterson approach proposed by Ganz et al1 prior to modifying the approach and we have previously reported the results of the radiological correction, length of stay, reduction in blood haemoglobin, duration of surgery between the original and the modified approach.19

The indications for surgery were symptomatic hip dysplasia that had failed non-surgical treatment with a centre-edge angle of Wiberg < 25° (LCE angle),20 acetabular index >10° (AI)21 and a congruent hip joint. The majority of patients (132 patients; 147 hips) had Tönnis Grade22 0 or 1 osteoarthritis.

Clinical evaluation. The demographic and clinical data collected are reported in Table I. Functional outcome was assessed using the Non Arthritic Hip Score (NAHS),23 University of California Los Angeles (UCLA)24 and Tegner score.25 These scores were recorded immediately pre-operatively, and at last follow-up appointment. We also documented a Sports score, which related to the four specific questions in the NAHS relating to sport and exercise. Patients were also assessed for signs of hypermobility using the Beighton criteria.26 Patient satisfaction with surgical outcome was also recorded: patients were asked whether they were very satisfied, quite satisfied or not satisfied with their surgery. A total of 96 patients (103 hips, 62%) had post-operative functional outcome scores available and 104 patients (113 hips, 68%) had pre-operative scores. In all, 66 patients (70 hips, 42%) had both pre- and post-operative outcome scores allowing direct comparisons.

Radiographic evaluation. Anteroposterior pelvic radiographs were performed for all patients pre- and post-operatively. Acetabular orientation was measured using the LCE angle20 and the AI of Tönnis.21 The pre-operative Tönnis grade osteoarthritis22 was recorded. To assess acetabular version the crossover percentage was measured before and after surgery. In hips that exhibited a positive crossover sign, the extent of crossover was measured by calculating the distance from the superolateral edge of the acetabulum to the point of crossover and expressing this as a percentage of the total acetabular diameter.27,28

To determine intra- and inter-observer reliability of radiographic measurements, pre- and post-operative radiographs were assessed for 20 patients by two authors (OK and DA), and repeated by one of the authors (OK). Radiographic data were then recorded for half the cohort of patients by each of the assessors.

Surgical technique. Our modification of the Smith-Peterson approach involves a skin crease incision below the level of the iliac crest (Fig. 1). The soft tissue is carefully dissected off the anterior superior iliac spine (ASIS) to include the origin of the inguinal ligament and sartorius. The LFCN is left within the fascial envelope of the sartorius and tensor fascia lata muscles, minimising the risk of injury to the nerve and its branches. The abdominal muscles are released.
off the iliac crest extending approximately 4 cm to 5 cm posterior to the ASIS. Distally the fascia over tensor fascia lata is incised for a distance of 5 cm to 6 cm staying lateral to the junction with sartorius and the muscle fibres are dissected off the fascia.

The direct head of rectus femoris is then identified and the interval between iliopsoas and rectus femoris is developed, leaving rectus femoris attached to the anterior inferior iliac spine (AIIS). The fibres of ilio-capsularis are elevated from the hip joint capsule, and just enough dissection is performed between iliopsoas and the hip joint capsule to allow the passage of a specialised osteotome down to the ischium (Fig. 2). The hip joint capsule is not opened, and bone cuts are made with the aid of dedicated osteotomes (Synthes, Salzburg, Austria) and intra-operative fluoroscopy (Fig. 3). The division of superior pubic ramus is next made under direct vision, after retracting the iliopsoas medially and clearing the soft-tissue attachments superiorly and inferiorly. Retractors are placed along the superior and inferior borders of the root of the ramus to protect the obturator nerve whilst the osteotomy is performed. The posterior column osteotomy is next made under fluoroscopic control (Fig. 4) to meet the ischial cut. The osteotomy is completed after making the transverse iliac osteotomy with a saw. A Schanz screw (DePuy Synthes) is inserted into the AIIS to aid re-positioning of the acetabular fragment. The acetabular fragment can be completely mobilised and the exposure itself does not limit the extent of the correction. This is judged by analysis of the posteroanterior (PA) pelvic view on the wide screen image intensifier. The tilt of the C-arm can also be adjusted to simulate the pelvic tilt as seen on the pre-operative radiographs. Fixation of the acetabular fragment is usually by

Fig. 1

Photograph showing the landmarks for the skin incision (patient supine, left hip). TFL, tensor fascia lata; ASIS, anterior superior iliac spine.

Fig. 2

Photograph and radiograph showing the dedicated osteotome positioned for the ischial osteotomy, with corresponding posteroanterior view from the image intensifier.

Fig. 3

Photograph and radiograph showing oblique view of ischial osteotomy with the image intensifier inclined at 45° to 50°.

Fig. 4

Radiograph showing completion of posterior column osteotomy at the corner with ischial osteotomy.
three long 4.5 mm cortical screws introduced from the iliac crest. The origin of the sartorius and the inguinal ligament is repaired back to the ASIS using fiberwire (Arthrex). The repair is robust and allows early functional mobilisation. An example of pre- and post-operative radiographs is shown in Figure 5.

Statistical analysis. This was undertaken using Excel (Microsoft Corporation, Redmond, Washington) and SAS software (SAS Inc., Cary, North Carolina). The continuous data were normally distributed (Shapiro-Wilk test) and hence the Student's $t$-test was applied. Chi-squared testing was undertaken for categorical data. Univariate regression analysis was performed with post-operative UCLA score as the dependent variable and age, gender, weight, duration of surgery, length of incision, grade of OA, hypermobility, change in haemoglobin level, change in LCE angle, change in AI, post-operative crossover percentage, stress fracture and pubic nonunion, as the independent variables. A p-value < 0.05 was considered statistically significant.

Results
Demographic data have been reported in Table I.

Radiographic analysis. The Tönnis grade was 0 or 1 for the majority of the patients (90%). A significant improvement (p < 0.001, $t$-test) in AI and LCE angle was noted post-operatively (Table II). The assessment of intraobserver error revealed a high degree correlation between the two observers for the measurement of both LCE angle (Kappa = 0.94, 95% CI 0.77 to 0.98) and AI (Kappa = 0.95, 95% CI 0.81 to 0.99).

Functional outcome scores. Significant improvements were recorded in all of the post-operative functional outcome scores (Table II). For the 96 patients with available post-operative scores, the majority (74 patients, 77.1%) were very satisfied with their surgery; 16 patients (16.7%) quite satisfied and 6 patients (6.3%) were not satisfied. 92 patients (95.8%) would recommend the operation to another person with the same condition.

Complications. There were no major neurovascular complications and no wound infections. Two patients (1.2%) required blood transfusion. In one patient a crack propagated through the posterior column during surgery which did not influence subsequent rehabilitation. One patient had a pulmonary embolism. There was variable altered sensation noted over the lateral femoral cutaneous nerve distribution, but this tended to improve markedly with time. One patient had a slight loss of correction in the post-operative period but made an otherwise uneventful recovery. A stress fracture was noted in 13 hips (7.8%) (12 involving the inferior pubic ramus and one in the posterior column). Two patients were converted to a total hip arthroplasty (THA). In one patient, aged 37 years, this was performed two years after the PAO as a result of progressive joint space narrowing. The second patient was 41 years old and developed a pubic nonunion and a posterior column stress fracture. Because of persistent symptoms that were thought to be joint related as well as possibly related to a fibrous

### Table II. Pre- and post-operative comparisons (mean values and 95% confidence intervals (CI))

<table>
<thead>
<tr>
<th></th>
<th>Pre-operative (95% CI)</th>
<th>Post-operative (95% CI)</th>
<th>p-value ($t$-test)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haemoglobin (gm/dl)</td>
<td>13.4 (13.23 to 13.57)</td>
<td>10.1 (9.93 to 10.27)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Centre-edge angle (*)</td>
<td>14.2 (13.19 to 15.21)</td>
<td>30.9 (30.12 to 31.68)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Acetabular index (*)</td>
<td>18.3 (17.2 to 19.4)</td>
<td>3.4 (2.59 to 4.21)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Crossover (%)</td>
<td>5.1 (3.4 to 6.8)</td>
<td>2.7 (1.6 to 3.8)</td>
<td>0.03</td>
</tr>
<tr>
<td>UCLA score</td>
<td>4.67 (4.38 to 4.96)</td>
<td>6.83 (6.51 to 7.15)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Tegner score</td>
<td>2.74 (2.49 to 2.99)</td>
<td>3.78 (3.53 to 4.03)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>NAHS score</td>
<td>58.7 (56.1 to 61.3)</td>
<td>82.9 (80.5 to 85.3)</td>
<td>&lt; 0.001</td>
</tr>
<tr>
<td>Sports score</td>
<td>2.89 (2.45 to 3.33)</td>
<td>3.01 (2.55 to 3.47)</td>
<td>&lt; 0.001</td>
</tr>
</tbody>
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UCLA, University of California, Los Angeles; NAHS, Non Arthritic Hip Score
union of the posterior column, a THA together with a posterior column plating was performed 18 months after
the PAO with a good outcome.

**Linear regression analysis.** Regression analysis indicated that none of the variables were significant predictors of post-operative UCLA score except hypermobility and duration of surgery (Table III). Presence of hypermobility was a significant negative predictor of the post-operative activity (coefficient: -1.06, p = 0.02) and the duration of surgery (coefficient: -0.03, p = 0.04) was also a significant predictor. Residual retroversion was also a significant positive predictor (coefficient 1.39, p = 0.049).

**Discussion**

We have described a new, safe and effective MIS approach for the Bernese PAO. Using this approach we have been able to demonstrate that good correction can be achieved, with satisfactory functional results and a low complication rate. We have previously presented the results of this approach with the conventional Bernese approach in the hands of the senior author (JDW) and have demonstrated the benefits of this approach in terms of reduction of length of stay, reduced blood loss and earlier rehabilitation without compromising the adequacy of correction or complication rate.18

The original technique described by Ganz et al1 involves an extensile Smith-Peterson approach,1,2 using a curved incision along the anterior third of the iliac crest and extending distal and lateral to the anterior superior iliac spine with an incision length of 15 cm to 20 cm. An osteotomy of the ASIS and elevation of the rectus femoris from the hip joint capsule and release of this from the ASIS is performed. The hip joint capsule is routinely opened. A Danish group using a trans-sartorial approach, successfully introduced the concept of a minimally invasive approach to PAO.17,29,30 The aim was to minimise tissue trauma during dissection without compromising patient safety, and allow optimal re-orientation of the acetabulum. In this technique, the hip joint capsule is not exposed; and there is no release of the rectus femoris and the ASIS osteotomy is not performed. This approach has been shown to produce equal
correction, less blood loss, earlier rehabilitation and good mid-long term results. However, the LFCN of the thigh is at risk31 during this approach and can lead to persistent dysaesthesia, which has been shown to lead to worse subjective outcome and dissatisfaction.3 LFCN nerve injury has been reported to be around 30% after modified Smith-Peterson approach, probably because of ischaemia of the nerve.32,33 Maintaining the nerve within the fascial sleeve of tensor fascia lata can be helpful in protecting the nerve.

Our study has shown that the minimally invasive approach to PAO developed by the senior author (JDW) is safe and allows optimal re-orientation of the acetabulum, with minimal trauma to the soft tissues. The abdominal muscles and the soft tissue at the level of the ASIS are dissected off the bone as a sleeve and re-attachment of the origin of the inguinal ligament and sartorius is robust using fibre wire through a drill hole in the bone at the end of the procedure. The sartorius and iliopsoas muscles protect the femoral nerve and vessels. We did not encounter any major neurovascular complications, however altered sensation in the distribution of the LFCN of the thigh was noted in some patients, none of whom complained of dysaesthesia in this region. The small incision (generally about 9 cm in length) is particularly desirable and appreciated by this predominantly female population. Complications after PAO have also been related to obesity,34 and the relatively low complication rate in our series may in part be related to the mean weight being 69 kg among our patients, however, there were 14 patients (14 hips) with a BMI of 30 or more.

Concern may be raised about passing between the rectus femoris and iliopsoas wherein lies the branch of the femoral nerve to the rectus femoris. This is not an extensile exposure in that interval because of the risk of injury to that nerve. We feel that this branch is not particularly at risk during this approach as the dissection is more medial rather than distal, and the focus is on elevating ilio-capsularis and iliopsoas from the hip joint capsule and the superior pubic ramus in order to open up the space down to the ischium. This is a minimally invasive approach, and therefore there is limited visualisation when performing the osteotomies.

### Table III. Results of linear regression analysis with the University of California, Los Angeles score as the dependent variable

<table>
<thead>
<tr>
<th>Variable</th>
<th>Coefficient</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>-0.01</td>
<td>0.68</td>
</tr>
<tr>
<td>Gender (male)</td>
<td>0.48</td>
<td>0.36</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.02</td>
<td>0.28</td>
</tr>
<tr>
<td>Duration</td>
<td>-0.03</td>
<td>0.04</td>
</tr>
<tr>
<td>Change in haemoglobin</td>
<td>-0.32</td>
<td>0.14</td>
</tr>
<tr>
<td>Length of incision</td>
<td>-0.37</td>
<td>0.15</td>
</tr>
<tr>
<td>Stress fracture</td>
<td>0.02</td>
<td>0.98</td>
</tr>
<tr>
<td>Pubic nonunion</td>
<td>0.45</td>
<td>0.36</td>
</tr>
<tr>
<td>Hypermobility</td>
<td>-1.06</td>
<td>0.02</td>
</tr>
<tr>
<td>Crossover (%)</td>
<td>1.39</td>
<td>0.049</td>
</tr>
<tr>
<td>Change in lateral centre edge angle</td>
<td>-0.01</td>
<td>0.76</td>
</tr>
<tr>
<td>Change in Acetabular Index</td>
<td>0.04</td>
<td>0.27</td>
</tr>
</tbody>
</table>

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There is a greater reliance on using intra-operative fluoroscopy compared with performing the extensile approach as described originally, but this has now become very much the norm and is routinely used by several authors. In our series there were no intra-articular extensions of the osteotomy. In one patient the osteotomy propagated a crack through the posterior column and this was stabilised with a screw introduced from the iliac crest.

The risk of requiring a blood transfusion with this procedure is very low and only two patients (1.2%) required a post-operative allogenic blood transfusion and this was related to a low-starting haemoglobin. A cell saver is routinely used in all cases.

One of the concerns is that with MIS techniques adequate correction cannot be obtained, leading to an adverse clinical outcome. Recent studies have however suggested that preservation of rectus femoris attachment is not essential for acetabular re-orientation and does not compromise correction. In our modification the rectus femoris tendon attachment is preserved and we have been able to show that the observed corrections obtained in both LCEA and AI using this approach demonstrate that both small and large re-orientation of the acetabulum can be achieved without compromise. In addition, we specifically looked at our accuracy in terms of correcting or achieving adequate acetabular anteversion with a mean post-operative crossover percentage of 2.7%. The lack of access to the hip joint requires a separate strategy to deal with the intra-articular abnormalities and our preference is to perform this arthroscopically usually at eight to ten weeks after the PAO when considered necessary.

The majority of patients who undergo PAO surgery are young adults. Many studies have used the Harris Hip Score (HHS) Short Form 36 (SF-36) and the Western Ontario kneeling young adults. Many studies have used the Harris Hip Score considered necessary.

We used the NAHS, UCLA and Tegner score to assess functional outcome following surgery. However, these scores have been developed to assess the condition of patients with osteoarthritis of the hip. There is evidence that these scores have a ceiling effect that would limit their use to assess functional outcome in the predominantly high demand, young patient population undergoing PAO. We used the NAHS, UCLA and Tegner score to assess functional outcome and found significant improvements in all three scores following surgery. The use of these scores allow for better demonstration of improved functional outcome following surgery which is more tailored to this specific patient group. Our questionnaire also revealed that this predominantly female population is very satisfied with the surgery, the cosmetic appearance and would recommend the surgery to someone else if they had the same condition. Interestingly, the results of the satisfaction survey suggested that a small percentage of patients (3%) were not satisfied with their surgery but would still recommend it to others. We feel the likely explanation for this is that there are some groups of patients whose outcomes can be uncertain, such as those with significant hypermobility. These patients carefully counselled before surgery and even though they may not achieve the outcome they wished, they recognise that the procedure is an effective treatment for the dysplastic acetabulum and most likely because the incision is rather small and the recovery not so difficult they still would recommend surgery to others with dysplasia.

Regression analysis has identified that the post-operative UCLA score may be negatively influenced by hypermobility and duration of surgery. MIS approach typically does help in reduction of surgical time, which may be a factor in improving outcome when compared with an extensile approach. We also found that the presence of residual crossover on the post-operative radiographs may have a positive influence on the post-operative UCLA score (coefficient = 1.39; p = 0.049). An explanation for this may be that the degree of crossover was small and therefore unlikely to lead to impingement but would be effective in increasing anterior coverage of the femoral head, which may have been the major factor of importance in these cases.

The main limitation of the study has been the inability to collect the outcome scores on all the patients, mainly because of the large geographical area from which these patients were referred, although we did have post-operative scores in almost 70% of the hips. We also acknowledge that there will undoubtedly be a learning curve with the use of this minimally invasive technique and we are reporting results from a high-volume centre where we have consistently used the approach in more than 250 further cases.

In conclusion, our technique of MIS PAO has benefits in terms of low complications, reduced blood loss and transfusion requirements, reduced length of stay, good functional outcome, high patient satisfaction and good radiological correction.

Take home message:
Minimally invasive periacetabular osteotomy does not compromise correction of acetabular parameters and has advantages in terms of recovery and patient experience.

Author contributions:
A. Malviya: Helped with statistical analysis and writing the paper.
O. Khan: Helped with radiological analysis, statistical analysis, and writing the paper.
P. Subramanian: Helped with retrieval of patient questionnaires.
D. Agolley: Helped with radiological analysis, and writing the paper.
J. Witt: Is the surgeon, who developed the novel surgical approach, operated on the patients and helped write the paper.

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References


