Triple osteotomy of the pelvis for acetabular dysplasia

AGE AT OPERATION AND THE INCIDENCE OF NONUNIONS AND OTHER COMPLICATIONS INFLUENCE OUTCOME

N. P. Hailer, L. Soykaner, H. Ackermann, M. Rittmeister

From the University Hospital for Orthopaedic Surgery Friedrichsheim, Johann Wolfgang Goethe-University, Frankfurt am Main, Germany

We investigated the variables which determine the outcome after triple osteotomy of the pelvis for the treatment of congenital dysplasia of the hip. We reviewed 51 patients (61 hips) with a median age at operation of 23 years who were treated with a Tönnis triple osteotomy. The median follow-up was six years with a minimum of two years. Eight patients (eight hips) required a revision procedure. Of the remaining 53 hips, the results were good or excellent in 36 (68%) when evaluated according to the Harris hip score (median 90 points), and 33 patients (65%) were satisfied with the procedure. Logistic regression analysis indicated that the incidence of complications such as nonunion at an osteotomy site influenced patient satisfaction (p = 0.079). The incidence of complications correlated positively with increasing patient age at operation (p = 0.004). The amount of acetabular correction did not correlate with patient satisfaction. In univariate analysis, the groups of 'satisfied' and 'not satisfied' patients differed significantly in Harris hip score, age, incidence of nonunion at the osteotomy sites, complications and late revisions. In conclusion, the patient's age at operation and the incidence of complications influence patient satisfaction after triple osteotomy, but the amount of radiologically evident acetabular correction shows no correlation to outcome.

Congenital dysplasia of the hip (CDH) is characterised by a poorly developed acetabulum which is frequently smaller and more steeply inclined than normal. The reduced area of the weight-bearing surface results in increased stress and premature cartilage degeneration, and there is an increased incidence of early secondary osteoarthritis of the hip. There is a correlation between the degree of dysplasia and the progression of osteoarthritis. Patients with a centre-edge (CE) angle of Wiberg < 16° are at higher risk than those with angles > 16°. In an attempt to prevent this progression, many osteotomies of the adult pelvis have been described including the Bernese periacetabular osteotomy developed by Ganz et al., the rotational osteotomy by Ninomiya and Tagawa and the triple osteotomy described by Steel. Tönnis, Behrens and Tscharani promoted a triple osteotomy which combined a standard innominate and superior pubic ramus osteotomy through an anterior approach with a high ischial osteotomy through a separate posterolateral approach. Good or excellent results have been reported for all these osteotomies. However, uncertainty remains as to the factors which influence the outcome following triple osteotomy.

The aim of this study was to investigate the variables that influence the outcome after triple osteotomy. The age of the patient at the time of the procedure, the incidence of pseudarthroses or other complications, the amount of acetabular correction, the pre-operative degree of osteoarthrits, the number of earlier operations, the degree of hip congruity and the body mass index (BMI) were assessed and correlated with relevant outcome measures such as standard scoring systems and patient satisfaction.

Patients and Methods

Between 1984 and 2000, 66 triple osteotomies in 55 patients (53 women and two men) were carried out at our institution. The median age at the time of operation was 23 years (8 to 44). Twenty hips had had previous operations: intertrochanteric femoral varus derotation osteotomy (14), Chiari osteotomy (two), Lance acetabuloplasty (one), open reduction (one), and in two hips combinations of an intertrochanteric varus derotation osteotomy and either Chiari or Lance osteotomy had been undertaken. In seven patients, the triple osteotomy was combined with femoral varus derotation osteotomy (six) or in one case with a shortening osteotomy.
In all patients, the operation as described by Tönnis, Kalchschmidt and Heinecke\textsuperscript{13} was adhered to in detail with regard to the position of the osteotomies. Three Kirschner (K-) wires of at least 2 mm strength were used for fixation of the iliac osteotomy following the correction of deformity. The osteotomies of the pubic and the ischium were not fixed. K-wires were routinely removed approximately one year after operation. Post-operative management always consisted of early mobilisation on crutches, without weight-bearing for six weeks. Prophylaxis for deep venous thrombosis was continued until full weight-bearing was achieved.

Of the 55 patients two were lost to follow-up and two died. Both deaths were related to pulmonary embolism. The remaining 51 patients (61 hips) were assessed with a questionnaire and clinical evaluation using the Merle d’Aubigné and Postel\textsuperscript{14} and Harris hip scores.\textsuperscript{15} Leg length was measured from the anterior superior iliac spine to the medial malleolus. The median follow-up was six years (2 to 16.9 years). Pre- and post-operative radiographs of 47 hips were independently evaluated by two physicians (LS, NPH) on separate occasions. The CE angle, the modified acetabular index\textsuperscript{16} and the Ullmann-Sharp angle,\textsuperscript{17} were recorded. Lateralisation of the hip pre- and post-operatively was determined by measuring the distance between a vertical line through the centre of the femoral head and a parallel line through the medial border of the acetabulum, defined by the tear drop. Lateralisation was expressed as a ratio of this distance divided by the diameter of the femoral head. Some patients were immature at the time of surgery and lateralisation relative to the diameter of the femoral head had to compensate for skeletal immaturity. The correction of lateralisation was calculated by subtracting pre- from post-operative measurements. Thus, numbers larger than zero indicate that no correction was achieved. The degree of osteoarthritis was determined on a scale of 0 to 3, according to acknowledged criteria.\textsuperscript{16} The radiographs taken at the time of follow-up were also examined for non-union of the pubis, ischium or ilium. A total of 14 hips were not reviewed radiographically.

Statistical analysis was used to investigate the relationship between the independent variables and the dependent variable ‘patient satisfaction’. The patients’ age at the time of the triple osteotomy, hip scores according to Merle d’Aubigné or Harris, the amount of correction (measured by the difference in CE angle, modified acetabular index, the Ullmann-Sharp angle, and the degree of hip lateralisation), the pre-operative degree of osteoarthritis, the number of previous operations, the incidence of complications, non-union, and the BMI were considered independent variables. Logistic regression analysis was performed using Wald’s backward elimination (with an elimination criterion of $\alpha \leq 0.1$) after dividing the patient population into ‘satisfied’ and ‘not satisfied’ groups.

Based on the findings made on multivariate analysis the ‘satisfied’ patients were compared with the patients that were ‘not satisfied’ by univariate analysis. The Wilcoxon-Mann-Whitney U test was applied when investigating independent numerical data. The Wilcoxon matched-pairs test was used to analyse dependent variables within individuals, e.g. the amount of radiographic correction, and the chi-squared test was used to investigate categorical data. A p value of $< 0.05$ was considered statistically significant.

**Results**

Eight patients (eight hips) required a late revision after triple osteotomy (‘failures’). In six cases the secondary operation was a total hip replacement (THR) and in two cases a Chiari procedure. The median time between the triple osteotomy and the revision was 40 months (8 to 132). In these patients, a radiograph at follow-up was not obtained, and their hip scores and findings on clinical examination were excluded from further analysis. Their degree of satisfaction, BMI, age at the time of triple osteotomy, number of previous operations, and complications were however included in the analysis. Radiographs taken after the triple osteotomy and shortly prior to revision were available in four of these patients, and the degree of osteoarthritis was determined. The remaining patients were revised at other institutions and radiographs taken before revision surgery were unobtainable.

**Clinical findings.** The majority of patients had good or excellent results. The median Merle d’Aubigné score was 10 (4 to 12) on a scale of 12 points, the median Harris hip score was 90 (35 to 100) on a scale of 100 points. A total of 33 (62%) hips were excellent or good according to Merle d’Aubigné, 14 (26%) had an outcome rated medium or fair, six (11%) had an outcome that was poor. This was consistent with the evaluation according to Harris, where 36 (68%) of the hips scored more than 80 points, 16 (30%) scored between 50 and 80, and one (2%) less than 50. When specifically asked whether they were satisfied with the outcome of the procedure, 18 of 51 patients (35%) were not, whereas 33 patients (65%) were satisfied. Two patients who received a THR after ten and 11 years, respectively were satisfied with the procedure, whereas the other six patients who had undergone late revisions were not satisfied.

Physical examination revealed that there was a median difference in leg length of 0.5 cm (0 to 4). The median range of extension/flexion was 130˚ (80˚ to 140˚), the median range of external/internal rotation in 90˚ flexion was 70˚ (35˚ to 40˚), the median range of abduction/adduction was 60˚ (40˚ to 120˚). Twenty-four (56%) patients had a limp, mostly due to a difference in leg length, 12 (29%) times a positive Trendelenburg’s sign was observed. Ipsilateral quadriceps wasting was noted in five (12%) cases. The median BMI at follow-up was 22.

We noted 13 complications. There were two post-operative cases of fatal pulmonary embolism. One patient had excessive bleeding from a branch of the internal iliac artery leading to discontinuation of the triple osteotomy pro-
procedure after haemostasis. This patient had a subsequent Chiari procedure. The other surgical complications included one large post-operative haematoma, two superficial wound infections that required revision, two temporary sciatic nerve palsies and two cases of heterotopic ossification requiring excision, one complete insufficiency of the gluteal muscles as a result of muscle avulsion and one false wound infections that required revision, two temporary sciatic nerve palsies and two cases of heterotopic ossification requiring excision, one complete insufficiency of the gluteal muscles as a result of muscle avulsion and one false wound infections that required revision, two temporary sciatic nerve palsies and two cases of heterotopic ossification requiring excision, one complete insufficiency of the gluteal muscles as a result of muscle avulsion and one false

**Radiographic findings.** The median pre-operative CE angle was 14° which improved significantly to 30° at the time of follow-up (p < 0.0005). The acetabular index and the Ullmann-Sharp angles also showed significant improvement. Relative lateralisation as an indicator of hip congruence was not significantly reduced (Table I).

The pre-operative degree of osteoarthritis of the hip was classified as absent (grade 0) in 38 (83%) hips and mild (grade 1) in 8 (17%). No hips were grade 2 or 3 osteoarthritis. Radiographs taken at follow-up showed no signs of osteoarthritis (grade 0) in 34 (72%) hips, mild osteoarthritis (grade 1) in 11 (23%) hips and grade 2 in two (4%) hips. There was no case of grade 3 osteoarthritis. No significant progression in the degree of osteoarthritis took place during the post-operative period. However, this did not apply to the eight patients whose hips were considered failures, where progression of pain and/or osteoarthritis made late revisions necessary. Nonunion at osteotomy sites was found in 13 (28%) hips in 12 patients. Isolated nonunion of the pubis occurred in six hips, and of the ischium in two hips. Five hips had combined pseudarthroses (pubis and ischium).

**Correlations.** Multivariate analysis showed that higher Harris hip scores (p = 0.02) and the absence of complications (p = 0.079) correlated with the dependent variable ‘patient satisfaction’. Increasing age at operation correlated with the incidence of complications (p = 0.004), and therefore contributed to ‘patient satisfaction’. The absence of complications was significantly correlated with higher Harris hip scores (p < 0.0005). These results do not preclude other independent variables exerting an influence upon patient satisfaction but these appear to be the most important.

Univariate analysis showed that patients in the group ‘not satisfied’ were significantly older (p = 0.005) and had significantly lower hip scores (p < 0.0005) (Table II). The incidence of nonunion at osteotomy sites (p = 0.017), complications (p < 0.0005), and failures (p = 0.014) was significantly higher in the ‘not satisfied’ group (Table II). The degree of radiologically evident acetabular correction did not differ significantly between the groups. There were no

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**Table I. Median (range) radiographic findings before and after triple osteotomy**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pre-operative</th>
<th>Post-operative</th>
<th>Correction</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Refined centre-edge angle (˚)</td>
<td>14 (14 to 31)</td>
<td>30 (12 to 70)</td>
<td>18 (0 to 42)</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>Modified acetabular index (˚)</td>
<td>23.5 (7 to 41)</td>
<td>9 (-6 to 35)</td>
<td>13.5 (1 to 33)</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>Ullmann-Sharp angle (˚)</td>
<td>49 (39 to 58)</td>
<td>36 (16 to 53)</td>
<td>12.5 (0 to 30)</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>Lateralisation (mm)‡</td>
<td>0.78 (0.65 to 1.07)</td>
<td>0.78 (0.65 to 1)</td>
<td>0.01 (-0.27 to 0.12)</td>
<td>0.447</td>
</tr>
</tbody>
</table>

* correction of lateralisation was calculated by subtracting pre- from post-operative lateralisation, thus, numbers larger than zero indicate that no correction of lateralisation was achieved. The Wilcoxon-matched-pairs-test was used to compare pre- with post-operative values, p < 0.05 was considered significant

‡ lateralisation was expressed relative to the femoral head diameter to compensate for skeletal maturation

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**Table II. Univariate comparison between the groups of patients who were ‘satisfied’ vs ‘not satisfied’ with the procedure at the time of follow-up. The two groups differ significantly in age, Harris hip score, Merle d’Aubigné score, the number of nonunions, complications and failures**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Satisfied</th>
<th>Not satisfied</th>
<th>p value*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Median age in yrs (range)</td>
<td>21 (8 to 43)</td>
<td>30 (8 to 44)</td>
<td>0.005</td>
</tr>
<tr>
<td>Median Harris hip score‡</td>
<td>93 (70 to 100)</td>
<td>67 (35 to 91)</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>Median Merle d’Aubigné score‡</td>
<td>10 (8 to 12)</td>
<td>8 (4 to 11)</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>Median body mass index</td>
<td>22 (16 to 33)</td>
<td>23 (19 to 37)</td>
<td>0.149</td>
</tr>
<tr>
<td>Median refined centre-edge angle correction (˚)</td>
<td>17 (0 to 42)</td>
<td>18 (8 to 28)</td>
<td>0.641</td>
</tr>
<tr>
<td>Median Ullmann-Sharp angle correction (˚)</td>
<td>13 (0 to 30)</td>
<td>11 (6 to 19)</td>
<td>0.735</td>
</tr>
<tr>
<td>Median modified acetabular index correction (˚)</td>
<td>11 (-6 to 33)</td>
<td>17 (3 to 26)</td>
<td>0.295</td>
</tr>
<tr>
<td>Median amount of correction of lateralisation (˚)</td>
<td>0.00 (-0.27 to 0.12)</td>
<td>0.01 (-0.10 to 0.08)</td>
<td>0.305</td>
</tr>
<tr>
<td>Nonunions (%)</td>
<td>5 (14)</td>
<td>6 (55)</td>
<td>0.017</td>
</tr>
<tr>
<td>Complications (%)</td>
<td>2 (5)</td>
<td>9 (47)</td>
<td>&lt; 0.0005</td>
</tr>
<tr>
<td>Post-operative degree of osteoarthritis ≥ 1 (%)</td>
<td>8 (23)</td>
<td>5 (42)</td>
<td>0.377</td>
</tr>
<tr>
<td>Previous operations (%)</td>
<td>13 (31)</td>
<td>7 (37)</td>
<td>0.873</td>
</tr>
<tr>
<td>Failures (%)</td>
<td>2 (5)</td>
<td>6 (32)</td>
<td>0.014</td>
</tr>
</tbody>
</table>

* the Wilcoxon-Mann-Whitney U test was applied when investigating independent numerical data; the Wilcoxon-matched-pairs-test was used to analyse dependent variables in individuals, e.g. the amount of radiographic correction and the chi-squared test was used to investigate absolute numbers (p < 0.05 was considered significant)

† correction is the difference between pre- and post-operative angles

‡ lateralisation was expressed relative to the femoral head diameter to compensate for skeletal maturation. Correction of lateralisation was calculated by subtracting pre- from post-operative lateralisation, thus, numbers larger than zero indicate that no correction of lateralisation was achieved.
significant differences between the groups in terms of BMI, the incidence of post-operative osteoarthritis or the number of previous operations.

Discussion

Some authors have shown a positive correlation between the degree of acetabular correction after pelvic osteotomy and the outcome; others have seen no such correlation. Our hypothesis was that other factors, such as the age of the patient at the time of the procedure or the incidence of complications during or after the operation, could exert an important influence on the outcome.

The patient population of this study was comparable to patients described in previous studies with regard to age, sex, prior operations, and complications. Our observations show that the triple osteotomy in its Tönnis modification gives good or satisfactory results in the majority of patients. This is in accordance with several studies where good results were found after different pelvic osteotomies. On the other hand, Peters et al., in a follow-up study nine years after 60 triple osteotomies, found that 27% had received a total hip replacement and another 27% were considered failures. Experience with the Bernese osteotomy showed that 49 of 75 hips required revision.

In our study, multivariate multivariate analysis confirmed that an older age and the incidence of complications was correlated with patient dissatisfaction. In contrast, there was no correlation between the stage of osteoarthritis pre-operatively, the number of previous operations, or the BMI and patient satisfaction. The single most important independent variable which contributed to patient satisfaction was a high Harris hip score. It therefore seems that the age of the patient at the time of triple osteotomy and the incidence of complications determine the overall outcome. In agreement with other authors, we found that neither the radiographic parameters (the CE angle, acetabular index, and Ulmann-Sharp angle), nor the amount of hip laterialisation correlated with satisfaction, although significant acetabular correction was achieved. Some authors, however, have demonstrated a positive correlation between the amount of correction with the outcome.

The parameters that influence the outcome after triple osteotomy have not been significantly investigated, although it has been incidentally reported that younger patients achieve better results than older patients. In accordance with our study, Koga et al. described that an age of 25 years or more was a significant risk factor in the progression of osteoarthritis following rotational acetabular osteotomy. Age probably does not directly influence outcome, and one can only speculate on the mechanisms that are to be held responsible for age-related effects. The efficacy of bone-healing is inversely related to age. This may explain the higher incidence of nonunion in older patients. Other complications such as deep-vein thrombosis or complications of wound healing also occur more frequently with increasing age. Among the factors that determine the long-term outcome after pelvic osteotomy the pre-operative function of the hip is of primary importance. Unfortunately, in the group of patients investigated in this study, pre-operative hip scores were not available. Future prospective studies will enable us to correlate pre- with post-operative scores in order to clarify this important point.

The complications observed in our patients have all been previously reported. Nonunion of one or several osteotomy sites deserves special attention, as one can assume that they severely alter the biomechanics of the pelvic ring resulting in pain or loss of mobility. Other investigators described nonunions in four of 51 hips (8%), two of 22 hips (9%), three of 21 hips (14%), seven of 48 hips (15%), and 13 of 409 hips (3.2%). Thus, the incidence of pseudarthroses in our patients, 28% of all hips, was higher than in previous studies. However, one study with four nonunions in eight hips (50%) has been published. In retrospect, one has to consider whether a more aggressive approach towards treating this complication might have improved the outcome in our patients. Alternatively, the method of screw and wire fixation of the pubis as described by Tönnis et al., and the method of K-wire fixation of the iliac osteotomy and the mobilisation protocols used at our institution should be critically reviewed. However, in all of the patients it was either the pubic or ischial osteotomy which developed a nonunion, and these osteotomy sites are not fixed by many authors, among them Tschauer et al. who reported a very low rate of nonunions. The incidence of smokers in our study is not known and thus the possible effects of smoking on bone healing could not be evaluated.

A further complication that deserves attention is the death of two patients due to pulmonary embolism following deep-venous thrombosis. To our knowledge, a systematic review of this complication following triple osteotomy has not been published, although incidental mention of pulmonary embolism has been made. It seems that our incidence of fatal pulmonary embolism is relatively high, as authors reporting on larger series have made no mention of this. Our policy on the prophylaxis of deep-venous thrombosis is in line with international recommendations.

In summary, our retrospective analysis of 61 triple osteotomies confirms that most patients achieve good or excellent outcomes when analysed by established scoring systems, and that most are satisfied with the procedure. Our study indicates that the age of the patient at the time of procedure and the incidence of pseudarthrosis and other complications influence patient satisfaction with the procedure. Younger patients are more likely to be satisfied, perhaps because they suffer fewer complications and nonunions at the osteotomy sites. Older patients, who develop nonunion at one or more osteotomy sites and those who suffer from other serious complications are less likely to be satisfied. The patients who were satisfied had a median age of 21 years at operation, whereas the dissatisfied patients had a median age of 30 years. Finally, at least in our
patients, the degree of radiologically visible acetabular correction did not influence the outcome after triple osteotomy.

No benefits in any form have been received or will be received from the commercial party related directly or indirectly to the subject of this article.

References