Polygonal triple (Kotz) osteotomy (over 10 years experience)

Cengiz Sen · Taner Gunes · Mehmet Erdem ·
Harzem Ozger · I. Remzi Tozun

Received: 6 May 2006 / Revised: 18 May 2006 / Accepted: 23 May 2006 / Published online: 17 August 2006
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Abstract We evaluated the results of polygonal triple (Kotz) osteotomy for the treatment of acetabular dysplasia over 10 years. This study included 31 hips of 27 patients who had the Kotz osteotomy for acetabular dysplasia. The mean age was 21.5 years. We performed the original Kotz osteotomy for the first 22 hips (group I), while the modified Kotz osteotomy through an intra-pelvic approach without damage to the abductor muscle was applied for the last 9 hips (group II). Patients were evaluated by clinically and radiologically. The average follow-up was 106 months in group I, and 18 months in group II. The Trendelenburg gait was unchanged for four patients in group I and for one patient in group II. The Harris Hip Score improved in all patients postoperatively. Radiographic assesment showed improvement in both groups in terms of the angle of CE, VCE, and Sharp postoperatively ($P<0.05$). The complication rate per hip was 0.29. The original Kotz osteotomy achieves adequate coverage for the treatment of acetabular dysplasia, and patients are generally satisfied by this procedure. Nonetheless, the modified Kotz osteotomy provides recovery of the abductor muscle strength in the early postoperative period and subsequently decreases the rate of the Trendelenburg gait compared to the original Kotz osteotomy.

Résumé Nous avons évalué le résultat de l'ostéotomie de Kotz dans le traitement des dysplasies acétabulaires sur une

période de 10 ans. Cette étude a inclus 31 hanches chez 27 patients. L'âge moyen était de 21.5 ans. Nous avons réalisé la technique originale de Kotz pour 22 patients (groupe 1) et la technique de Kotz modifiée chez 9 patients (groupe 2). Les patients ont été évalués sur le plan clinique et radiologique. Le suivi moyen a été de 106 mois pour le groupe 1 et de 18 mois pour le groupe 2. Une boiterie de type Trendelenbourg a persisté chez 4 patients du groupe 1 et 1 patient du groupe 2. Le score de Harris post opératoire a été amélioré chez tous les patients. L'amélioration radiographique a été constatée dans les deux groupes sur l'angle CE et VCE et l'angle de Sharp ($P<0.05$). Le taux de complication a été de 0.29. La technique originale de Kotz donne de bons résultats quant à la couverture de la hanche, cependant la technique de Kotz modifiée permet de récupérer plus rapidement une force importante des muscles abducteurs en post opératoire et ce fait diminue le pourcentage de patients présentant une boiterie de type Trendelenbourg.

Introduction

Acetabular dysplasia of the hip in adolescents and young adults is well known as a main cause of secondary osteoarthritis of the hip [1–3, 12, 18, 21, 22]. Although total hip arthroplasty is an alternative treatment in acetabular dysplasia, this option has been reserved for cases of severe osteoarthritis of the hip [12, 22]. Therefore, biological reconstructive methods have gained popularity in the last 15 years. These methods can be divided into either reconstructive or salvage procedures. Salvage osteotomies such as the Chiari and shelf are indicated for patients with osteoarthritis and hip instability that are not requiring reorientation of the acetabulum [12, 22]. In contrast, several

C. Sen (✉) · T. Gunes · M. Erdem
Medical School of Gaziosmanpasa, University of Gaziosmanpasa,
Tokat, Turkey
e-mail: senc64@yahoo.com

H. Ozger · I. R. Tozun
Medical School of Istanbul, University of Istanbul,
Istanbul, Turkey

methods for reorientation of the acetabulum have been described. The aims of a reorientation osteotomy are to reduce the symptoms and prevent or delay osteoarthritis in adolescents and young adults by achieving better coverage and congruency of the hip [7, 12, 18, 22]. Polygonal triple osteotomy was first described by Kotz as a technique also called reorientation osteotomy [10]. Since 1992, we have used this technique to treat acetabular dysplasia in young patients. We have modified this technique through the medial pelvic approach to avoid the Trendelenburg gait, which is the most important complication of the original Kotz osteotomy [10, 15, 16]. We evaluated our experience over 10 years in patients with acetabular dysplasia who underwent either an original or modified Kotz osteotomy.

Materials and methods

We treated 22 dysplastic hips in 20 patients with a mean age of 24.3 years (group I) using the original Kotz osteotomy first, while the modified Kotz osteotomy through a medial pelvic approach was applied for 9 dysplastic hips in 7 patients with a mean age of 19.2 years (group II). In all patients except one, acetabular dysplasia was due to developmental hip dysplasia. The indications for surgery were hip pain and limping for more than 6 months, radiographic presence of acetabular dysplasia as determined by a centre edge angle (CE) of Wiberg below 20° , a vertical centre edge angle (VCE) below 30° , a Sharp's angle above 40° , nearly normal congruency between the femoral head and acetabulum, and an almost full range of hip motion [22].

We used the Harris Hip Score (HHS), Trendelenburg test, impingement test, apprehension test, daily activities and abductor muscle strength for clinical evaluation.

Abductor muscle strength was measured according to the Medical Research Council muscle power grading system [8]: grade 0, no palpable contraction of the muscle; grade 1, palpable contraction of the muscle and no motion of the part that muscle should move; grade 2, the muscle moves partly through its range, but not against gravity; grade 3, the muscle carries partly through its range of motion against gravity, but not against added resistance; grade 4, the muscle lifts partly against gravity and added resistance; grade 5, normal strength.

For radiographic evaluation, we used the CE angle, VCE angle and Sharp angle [9]. In addition, we evaluated patients for osteoarthritis using the Tönnis classification: grade 0, no signs of osteoarthritis; grade 1, increased sclerosis, slight narrowing of the joint space and no or a slight loss of head sphericity; grade 2, small cysts, moderate narrowing of the joint space and moderate loss of head sphericity; grade 3, large cysts, severe narrowing or obliteration of the joint space and severe deformity of the head [18].

The statistical differences between the preoperative and follow-up, functional and radiological results were analysed with a paired t-test. For comparison between both groups with different variables, the Mann-Whitney U test was applied. Significance was determined to be $P < 0.05$.

Surgical technique

For the original Kotz osteotomy [10], we used the same technique with ilioinguinal and ischial incisions (Fig. 1a and b) [16].

For the modified approach, the patient lies in the lateral decubitus. A curvilinear incision begins along the border of the iliac crest, and it ends just at or below the inguinal crease. To avoid injury to the lateral femoral cutaneous nerve, deep exposure is performed between the tensor fascia lata and sartorius. Then the sartorius muscle is released from the anterior superior iliac spine, and the direct head of the rectus femoris is mobilised from the anterior inferior iliac spine. After that, the inner iliac wing is exposed down to the sciatic notch by removing iliac muscle from the bone and capsule, and a Hohmann retractor is placed to retract the iliopsoas medially. Furthermore, another Hohmann retractor is placed at the sciatic notch laterally in order to see the iliac osteotomy better. During the iliac osteotomy and its fixation, no dissection of the abductor muscles is performed. Then, ischial exposure is performed. Finally, iliac, pubic and ischial osteotomy are completed by using both exposures. After finishing three osteotomies, the acetabular fragment is rotated anterolaterally with a Steinman pin or chisel (Fig. 2a–d). Fixation was done with two to three spongy screws placed crosswise (Fig. 3a–d).

External support was not used. Partial weight bearing was allowed at 6 weeks and full weight bearing at 12 weeks.

Fig. 1 **a** In the original Kotz osteotomy, the abductor muscle is detached from the origin. LW: lateral wall; white arrow: spina iliaca anterior superior. **b** The view of the iliac osteotomy from the lateral side is demonstrated

Results

Patients in group I were followed for a mean of 106 (80–136) months and group II for 18 (14–29) months. Moreover, we found the operation time to have a mean of 120 (90–150) min in group I, and 95 (75–130) min in group II ($P<0.05$). The blood loss was determined to be 700 (500–900) cc on average in group I and 450 (350–700) cc in group II ($P<0.05$). There were no differences in the postoperative rehabilitation programs between the two groups.

Clinical results

In group I, 15 patients had no pain at the follow-up. Five patients complained of pain developing after more than 1 h of walking. In group II, none of the patients had pain postoperatively. Nonetheless, five hips in group I continued

to limp because of gluteal weakness in four and leg length discrepancy in one patient. The four patients recovered after intensive physiotherapy for 1 year. In group II, one patient limped because of gluteal weakness and recovered after intensive physiotherapy for 3 months.

In group I, abductor muscle strength was measured as normal after 3 months in 15 patients. Five patients had 4/5 power at follow-up. In contrast, all patients had normal abductor muscle strength at the end of 3 months postoperatively in group II ($P<0.05$).

HHS increased 12 points on average in group I and 29 points in group II. As compared with preoperative hip motion, we determined a loss of active flexion by an average of 13° (5° – 20°), but movement in all other planes was normal, except for one patient with a 30° limitation of internal rotation in group I. We found a loss of active flexion of an average of 5° (0° – 10°) in group II. No leg length discrepancy was observed except in one patient with 3.5 cm shortening in group I. Regarding daily activities, all patients continued the same activities and their jobs postoperatively in both groups, as well as jogging and swimming. We did not find a sign in either group by applying impingement and apprehension tests postoperatively.

Radiological results

An improvement of the average CE angle was 35° (20° – 46°) in group I and 36° (16° – 46°) in group II, while the mean VCE angle improved by 31° (15° – 55°) in group I and 29° (22° – 51°) in group II ($P>0.05$). The average Sharp's angle decreased 20° (3° – 28°) in group I and 19° (4° – 30°) in group II ($P>0.05$). Using the Tonnis classification, an improvement was seen 12 hips in group I, whereas 9 hips remained unchanged and 1 deteriorated. Nonetheless, no difference was found in group II.

Further details of the clinical and radiological results are given in Tables 1 and 2. Table 3 contains the statistical analysis between groups in terms of the average improvement.

Complications

In group I, superficial infection was seen in three patients. They were treated with appropriate systemic antibiotics and local dressing. Peroneal paralysis was found in three patients, but they recovered with intensive physiotherapy and splints. Asymptomatic non-union of the pubic bone occurred in one patient and of the ischial bone in two patients. In group II, one patient (case no. 1) did not have adequate coverage because of a failed osteotomy. In this patient, we consider that the cause of failure was a very thin iliac wing and a too low osteotomy level.

Fig. 2 **a** In the modified technique, an ilioinguinal incision is shown. **b** Osteotomy lines are shown on the model from the medial side. **c** Figure demonstrates the view after iliac osteotomy. **d** Fixation was performed using two spongy screws. AR: amount of rotation. It shows the amount of acetabular rotation after three osteotomies. MW: medial wing. AM: abductor muscles. Dotted red lines: osteotomy lines; blue line: osteotomy line of the ilium performed through the medial side

Fig. 3 **a** and **b** X-rays demonstrate AP and false profile view preoperatively. **c** and **d** Images show AP and false profile view at final follow-up

Discussion

Developmental hip dysplasia is a structural hip disease that can give rise to osteoarthritis of the hip joint. The most important biomechanical factor of osteoarthritis is an excessive load pressure on the osteocytes and chondrocytes beyond their capacities due to the reduction in the weight-bearing surface [1–3, 18, 21].

The aim of osteotomy is to provide coverage of the femoral head by a surface of hyaline cartilage, to reduce contact pressure on the weight-bearing area and to prevent or delay the onset of secondary osteoarthritis. The most biological solution in adolescent and young patients with a dysplastic hip seems to be restoration of a normal position between the femoral head and acetabulum by doing a reorientation osteotomy [12, 22]. Reorientation osteotomies include single, double, triple and various periacetabular osteotomies, which have been used frequently in the last 2 decades [22]. Rotational acetabular osteotomy as described by Ninomiya is an effective surgical option for the treatment of dysplastic hips [14]. Matsui et al. reported that there was a 40% prevalence of chondrolysis and collapse of the transferred acetabulum in 19 hips [11].

Bernese periacetabular osteotomy, developed by Ganz [7] and modified by Millis and Murphy [13], has many

advantages compared with previously described reorientation osteotomies [19].

However, this osteotomy has some disadvantages, such as a long and difficult learning curve, the requirement for fluoroscopy during the osteotomies and some major complications, especially in the first part of the experience. The complication rate of the Bernese osteotomy has been reported to be from 0.17 to 1.28 per patient [4, 5, 15]. Nonetheless, it has been noticed that the majority of these complications occurred during the long learning curve, and the complication rate gradually decreased as the surgeon gained experience [7, 12, 13, 15, 19, 20].

The polygonal triple (Kotz) osteotomy described by Kotz [10] is one of the reorientation osteotomies. The Kotz osteotomy has many advantages compared with previously described triple osteotomies: (1) It achieves a larger amount of correction because of its polygonal design and the close proximity of the osteotomies to the acetabulum; (2) there is no need for external support with stable osteosynthesis, which allows early weight bearing and mobilisation; (3) adequate stability can be provided using only two to three spongy screws [10, 16, 17]. Furthermore, it has a few superior elements compared to the Bernese osteotomy. (1) It allows all osteotomies to be performed under direct vision without the need of an image intensifier; (2) its

Table 1 All patient details for group I

Patient	Age	Previous treatment	Follow-up (months)	Pain	Trendelenburg		Harris Hip Score		CE angle		VCE angle		Sharp angle		Hip arthritis (Tönnis)		Abductor muscle strength		
					Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	At 1st month	At 3rd month	
1	23	–	86	Yes	No	Positive	Negative	65	98	5	35	8	48	55	35	1	0	3	5
2	28	–	98	Yes	No	Negative	Negative	75	90	0	40	0	35	55	33	1	1	3	5
3	28	Open reduction	80	Yes	Yes	Positive	Positive	70	74	–40	6	5	20	50	47	3	0	2	4
4	23	–	82	Yes	No	Negative	Negative	90	90	0	30	10	35	55	34	1	1	3	5
5	17	Cast	108	Yes	Yes	Negative	Negative	80	85	–3	30	–5	32	60	35	2	1	3	5
6(L)	18	Cast and PFO	131	Yes	Yes	Positive	Positive	60	70	–30	12	–22	20	60	50	2	1	2	4
6(R)	18	Cast and PFO	135	Yes	No	Positive	Positive	70	72	–35	5	–25	15	72	45	3	3	2	4
7	19	Cast	115	Yes	No	Positive	Negative	80	95	0	40	5	42	54	30	2	1	3	5
8(R)	33	Open reduction	136	Yes	No	Negative	Positive	70	80	5	25	0	30	55	35	3	3	2	4
8(L)	33	–	126	Yes	No	Negative	Positive	80	82	–15	10	–5	20	60	43	2	3	2	4
9	17	–	103	Yes	No	Positive	Negative	80	91	–5	27	15	35	55	35	0	0	3	5
10	24	Cast	107	Yes	No	Positive	Negative	75	88	–5	35	–15	40	50	35	2	0	3	5
11	25	Cast	118	Yes	No	Positive	Negative	80	92	6	46	10	30	58	30	1	0	3	5
12	27	–	91	Yes	No	Negative	Negative	85	95	0	40	19	48	53	35	1	0	3	5
13	24	Open reduction	102	Yes	Yes	Positive	Negative	80	88	2	40	20	50	53	38	1	1	3	5
14	27	–	110	Yes	No	Positive	Negative	80	95	2	35	18	40	60	35	1	0	3	5
15	29	–	88	Yes	No	Positive	Negative	75	88	0	40	20	41	57	38	0	0	3	5
16	30	Cast	130	Yes	No	Negative	Negative	65	85	0	35	20	45	60	35	3	1	3	5
17	28	Open reduction	125	Yes	No	Positive	Negative	70	90	4	35	12	43	50	35	0	0	3	5
18	34	Open reduction	112	Yes	No	Positive	Negative	72	95	14	41	17	55	55	40	4	2	3	5
19	15	–	93	Yes	No	Negative	Negative	75	88	–5	28	0	32	70	45	0	0	3	5
20	16	Open reduction	83	Yes	Yes	Positive	Negative	70	80	0	32	10	42	65	40	3	1	3	5

R: right; L: left; PFO: proximal femoral osteotomy; CE: center edge; VCE: vertical center edge

Table 2 All patient details for group II

Patient	Age	Previous treatment	Follow-up (months)	Pain	Trendelenburg		Harris Hip Score		CE angle		VCE angle		Sharp's angle		Hip arthritis (Tönnis)		Abductor muscle strength		
					Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	Preop	Postop	At 1st month	At 3rd month	
1(R)	18	–	29	Yes	No	Positive	Negative	71	97	–7	35	–9	42	52	42	2	2	3	5
1(L)	18	–	19	Yes	No	Positive	Negative	62	84	–4	12	–13	18	58	54	1	1	3	5
2(R)	16	–	24	Yes	No	Positive	Negative	64	83	–9	37	10	36	52	31	2	2	4	5
2(L)	16	–	16	Yes	No	Positive	Negative	68	100	–2	38	10	36	56	26	1	1	4	5
3	33	Hip arthroscopy	15	Yes	No	Negative	Negative	69	96	12	54	20	44	51	32	2	2	4	5
4	27	–	16	Yes	No	Positive	Negative	55	95	2	45	20	51	54	30	3	3	3	5
5	18	–	15	Yes	No	Negative	Negative	71	100	13	42	14	41	44	28	1	1	4	5
6	14	Pelvic support osteotomy using Ilizarov	14	Yes	No	Positive	Negative	51	88	–9	29	10	32	55	36	2	2	3	5
7	13	Open reduction and innominate osteotomy	14	Yes	No	Positive	Negative	61	92	2	35	12	34	56	30	2	2	3	5

R: right; L: left; CE: center edge; VCE: vertical center edge

learning curve is not too long and difficult because it is technically easier than the Bernese osteotomy [15].

In this study, we found an improvement with a mean of 12 points in the Harris Hip Score, 35° in the CE angle, 31° in the VCE angle and 20° in the Sharp's angle in group I, while 28 points in the HHS, 36° in the CE angle, 29° in the VCE angle and 19° in the Sharp's angle in group II, respectively. These findings are not significantly different between both groups except the HHS, while a statistical difference was found in each group according to the preoperative scores. Furthermore, our results are slightly superior compared with other triple osteotomies [6, 9].

Although the Kotz osteotomy achieves good coverage and satisfactory functional results postoperatively, it has some disadvantages. The most important complication of the Kotz osteotomy is postoperative limping due to the complete stripping of the abductor muscle. The study conducted by Kotz reported that limping continued in three patients postoperatively even though those patients had no limping preoperatively [10]. Another study reported by Sen et al. demonstrated that limping continued in four patients because of gluteal muscle weakness postoperatively [16]. Both of those patients limped preoperatively, while two of them did not limp preoperatively.

The aim of changing our exposure by doing a Kotz osteotomy is to accelerate the recovery of the abductor muscle and to reduce the rate of the Trendelenburg gait compared with the original Kotz osteotomy Trousdale et al. reported finding slower healing of the bone, slower recovery of the abduction and improvement in the postoperative limp by doing the original Ganz technique. However, they determined an improvement in the rate of healing time to weight bearing, and limping, when they changed the exposure by leaving the outer aspect of the ilium completely intact [19].

In this study, we found that the Trendelenburg gait was unchanged in four patients (18%) in group I, while it continued in only one patient (14%) in group II. Furthermore, recovery of the abductor muscles needed significantly less time in group II compared with group I ($P<0.05$). We consider that these findings resulted from leaving the origin of the abductor muscles intact. Regarding the morbidities of both osteotomies, the operative time and blood loss were significantly less in group II. This may be related to our current approach.

A few weaknesses of the current study are given below: (1) the shortness of the follow-up period and lesser number of patients in group II that was not able to be compared with group I properly; (2) we could not compare the prediction of osteoarthritis between both groups concerning the prevention or delay of osteoarthritis, which is one of the important goals for the treatment of acetabular dysplasia. Therefore, these findings should be supported

Table 3 Statistical analysis between groups

Clinical and radiological results		Original Kotz group Group I <i>n</i> =22 (average improvement)	Modified Kotz group Group II <i>n</i> =9 (average improvement)	Statistical difference	
Harris Hip Score		12.45±8.06	29.56±6.65	S	<i>t</i> =5.612, <i>P</i> =0.0001
CE angle		34.86±6.31°	36.56±9.32°	NS	<i>t</i> =0.588, <i>P</i> =0.561
VCE angle		30.95±9.23°	28.89±8.92°	NS	<i>t</i> =0.571, <i>P</i> =0.573
Sharp angle		19.82±6.00°	18.78±8.01°	NS	<i>t</i> =0.397, <i>P</i> =0.694
*Abductor muscle strength	1st month	2.77±0.42	3.44±0.52	S	<i>t</i> =3.706, <i>P</i> =0.001
	3rd month	4.77±0.42	5.00±0.00	S	<i>t</i> =2.485, <i>P</i> =0.021

S: significant; *average postoperative values

with other studies with more patients and a longer follow-up. However, we believe that one can achieve good coverage of the hip joint and satisfactory functional results by applying both techniques as well as other periacetabular osteotomies. The important complications of the original Kotz osteotomy may be decreased by evolving this technique.

The purpose of this study was not to compare both techniques, but to share the results of our experience over 10 years for the treatment of acetabular dysplasia. In the light of our experience, we would like to highlight some of our findings for surgeons who deal with the treatment of acetabular dysplasia. Furthermore, our expectation when doing this osteotomy is that satisfactory functional and radiological outcomes can be achieved in the long-term. Otherwise, the improved acetabular coverage and bone stock would be a better place to fix the acetabular cup in case of conversion to a total hip arthroplasty in the future.

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