



# Early and mid-term results of Tönnis lateral acetabuloplasty for the treatment of developmental dysplasia of the hip

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Developmental dysplasia of the hip (DDH) is one of the most common musculoskeletal diseases in childhood and is a common reason for severe adult osteoarthritis if left untreated.<sup>[1]</sup> Early diagnosis and treatment are necessary. A late diagnosis results in different bony procedures, such as Tönnis lateral acetabuloplasty (TLA).<sup>[2]</sup>

Despite the improvements in the early diagnosis of DDH, surgical interventions are still needed in treatment. Various type of procedures has been described to improve the coverage of dysplastic hips. It has been shown that 58% of patients older than 18 months who underwent closed reduction and 19% of those who underwent open reduction require an additional pelvic osteotomy for acetabular dysplasia.<sup>[3]</sup> Pelvic osteotomies can be categorized as redirection, reorientation, and salvage osteotomies.<sup>[4]</sup> The Tönnis technique is an acetabuloplasty technique that

## ABSTRACT

**Objectives:** This study aimed to present the clinical and radiological results of a large patient group operated by Tönnis lateral acetabuloplasty (TLA) for developmental dysplasia of the hip (DDH).

**Patients and methods:** The retrospective study was conducted with 66 hips of 41 patients (5 males, 36 females; mean age: 32.3±18 months; range, 11 to 132 months) operated for DDH using the TLA technique in a single center between February 2012 and December 2016. Adductor tenotomy was performed on 52 (79%) hips. There was a need for additional femoral shortening and derotation-varization osteotomy in 14 (21%) hips. Clinical outcomes were evaluated with modified McKay criteria. The acetabular index and lateral migration index for the subluxated hip were calculated, and the femoral head position was evaluated according to Perkin's line and Shenton's line. The Severin classification was used to assess the outcome of the hips.

**Results:** The mean follow-up period was 27±11 months. According to the modified McKay criteria for DDH, 77.3% of hips were classified as excellent, 16.6% as good, and 6.1% as fair. The mean acetabular index decreased from 36.1° preoperatively to 18.6° postoperatively. The mean postoperative improvement for the acetabular index was 17.5±5. The lateral migration index improved from 89.7 to 10.6%. A statistically significant difference was determined between the preoperative and postoperative measurements of the acetabular index and lateral migration index (p<0.001).

**Conclusion:** Tönnis lateral acetabuloplasty was found to be safe and effective with a low learning curve, and successful treatment decreases the duration of follow-up required in patients with DDH.

**Keywords:** Acetabuloplasty, developmental dysplasia of the hip, osteotomy, Tönnis.

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repositions the acetabulum to improve the anterior and superolateral coverage of the femoral head.<sup>[5]</sup>

Although TLA has not gained much popularity among other periacetabular or complete osteotomies that may be preferred, current publications present

promising results.<sup>[6-8]</sup> To the best of our knowledge, the present study includes one of the largest patient groups to have undergone TLA surgery. This study aimed to present the clinical and radiological results of patients operated on by TLA for DDH.

## PATIENTS AND METHODS

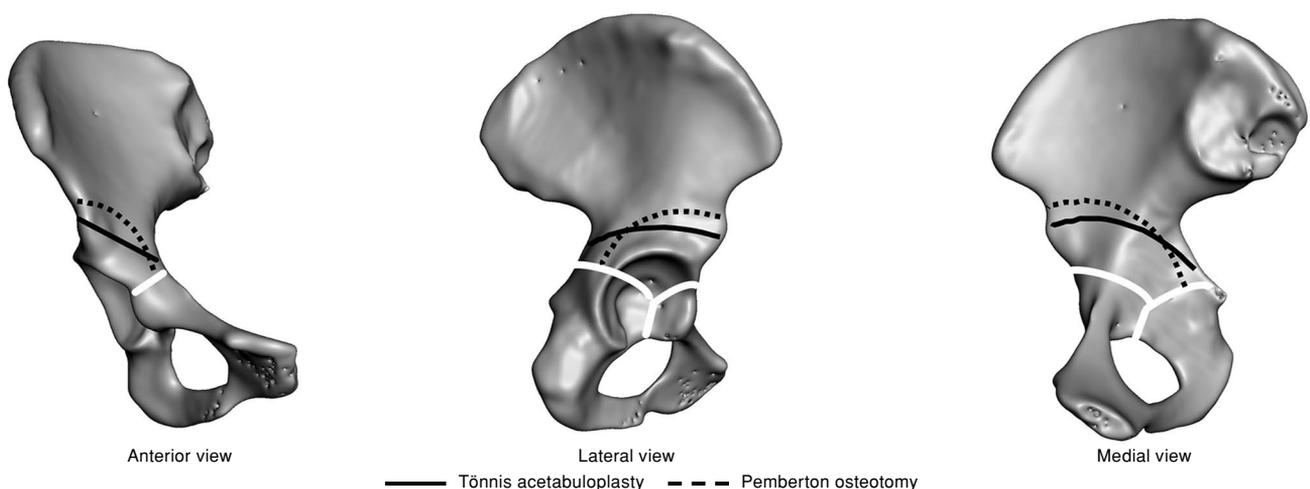
The retrospective study included 41 patients (5 males, 36 females; mean age: 32.3±18 months; range, 11 to 132 months) who underwent TLA surgery for DDH in a single center between February 2012 and December 2016. The patients that had undergone surgery for DDH using the TLA technique, those with a follow-up period of less than 12 months, and patients with a teratological hip dislocation were excluded from the study. Bilateral involvement was observed in 25 patients and unilateral involvement in 16 patients. Family history was positive for eight (19.5%) patients. Tönnis lateral acetabuloplasty was performed on nine patients (14 hips), even though they were younger than 18 months, to avoid wasting time in the treatment since closed reduction was performed and the safe zone was insufficient. A written informed consent was obtained from the patients' parents. The study was approved by the institutional review board of the authors' affiliated institution (decision no: 2016/299). The study was conducted in accordance with the principles of the Declaration of Helsinki.

A detailed physical and radiological examination was preoperatively performed for all patients. Radiological examinations were made from anteroposterior pelvis radiographs taken with the hip in a neutral position, in the von Rosen view, in which both hips are abducted, internally rotated, and extended, and in the frog-leg view with the hips

flexed, abducted, and externally rotated. The hips were classified according to the Tönnis classification for DDH,<sup>[9]</sup> and 10 (15.1%) hips were observed to be Grade II, 18 (27.2%) hips were Grade III, and 38 (57.5%) hips to be Grade IV.

The senior author performed all surgical procedures. The surgery was performed under general anesthesia while the patient lay in a supine position on a radiolucent table. A Smith-Peterson incision was used in all patients. Open reduction was performed following the capsulotomy and removal of the obstacle to the reduction in all patients.

Under fluoroscopy guidance, a straight acetabular osteotomy was performed on the iliac lateral wall, 5 to 8 mm above the acetabular rim, in the posterior inferior direction, close to the posterior branch of the triradiate cartilage, using a sharp and flat osteotome instead of the curved osteotome as in the Pemberton method. The osteotomy was started from lateral to medial and then proceeded from ventral to dorsal, ending just above and parallel to the triradiate cartilage (Figure 1). The iliac osteotomy was performed under the guidance of a previously inserted K-wire. After completing the cuts on both the lateral and medial cortices of the ilium, the distal part was laterally and distally bent to cover the femoral head. Unlike Pemberton's curved osteotomy line, in TLA, the osteotomy ends near the triradiate cartilage before reaching the greater sciatic notch. Therefore, the triradiate cartilage itself becomes the hinge point for rotation. A triangular bone graft harvested from the iliac wing, including the superior anterior iliac spine, was placed into the osteotomy site (Figure 2 and 3).



**FIGURE 1.** The osteotomy lines of Tönnis lateral acetabuloplasty and Pemberton osteotomy in anterior, lateral, and medial views.

Femoral osteotomy was performed in nine patients (14 hips; 21%), in whom we had difficulty in the reduction of the femoral head after osteotomy. If reduction with restricted hip motions was achieved, a femoral osteotomy was preferred to prevent avascular necrosis of the femoral head. In these patients, combined femoral derotation-varization and shortening osteotomies were performed (Figure 4 and 5). Additional adductor tenotomy was performed in 52 (79%) hips.

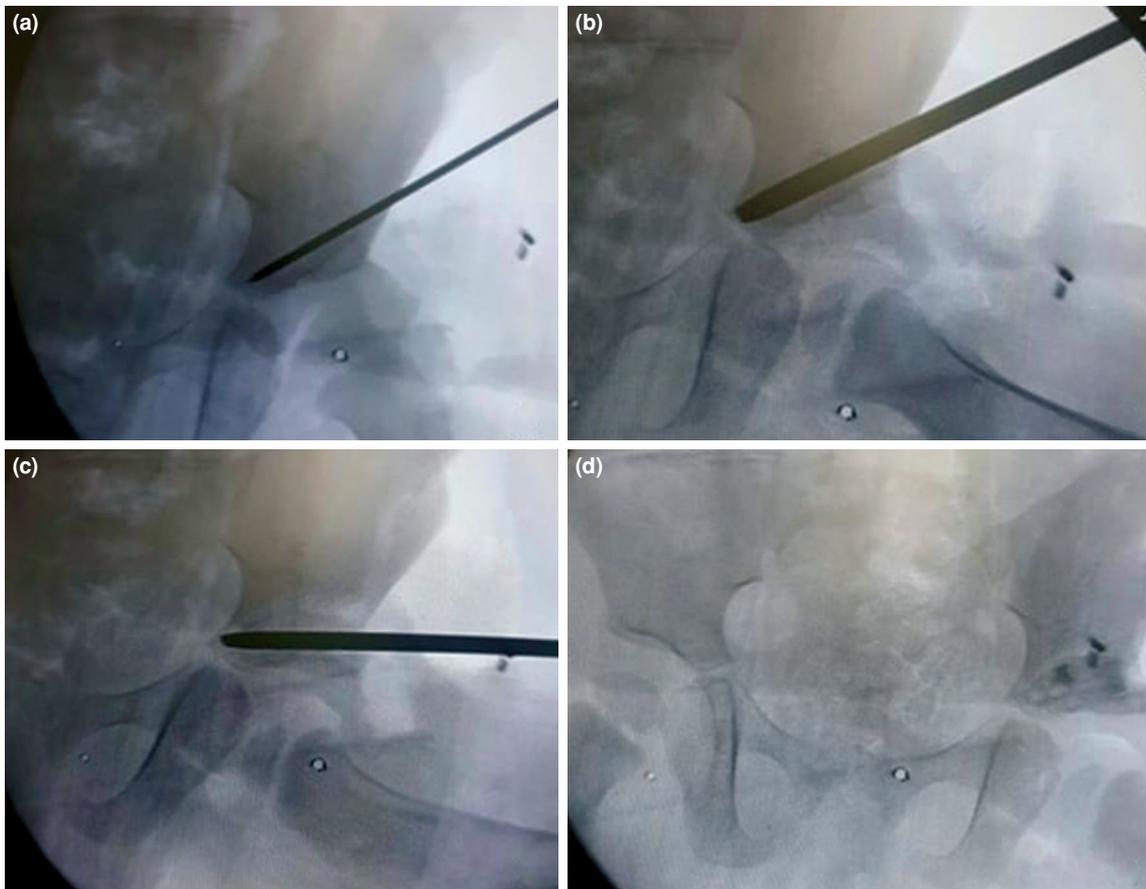
A one and a half hip spica cast (spica extending to just above the malleolus on the affected side and above the knee on the unaffected side) was applied to all patients. The mean follow-up period was  $27 \pm 11$  (range, 12 to 47) months. The first two follow-up examinations were made at three and six weeks postoperatively, then at three-week intervals until the third month and every three months after that until the end of one year. After one year, all patients

were examined once a year. The cast was removed in the sixth postoperative week for all patients. A Scottish-Rite abduction orthosis was used full-time for six weeks following the cast removal.

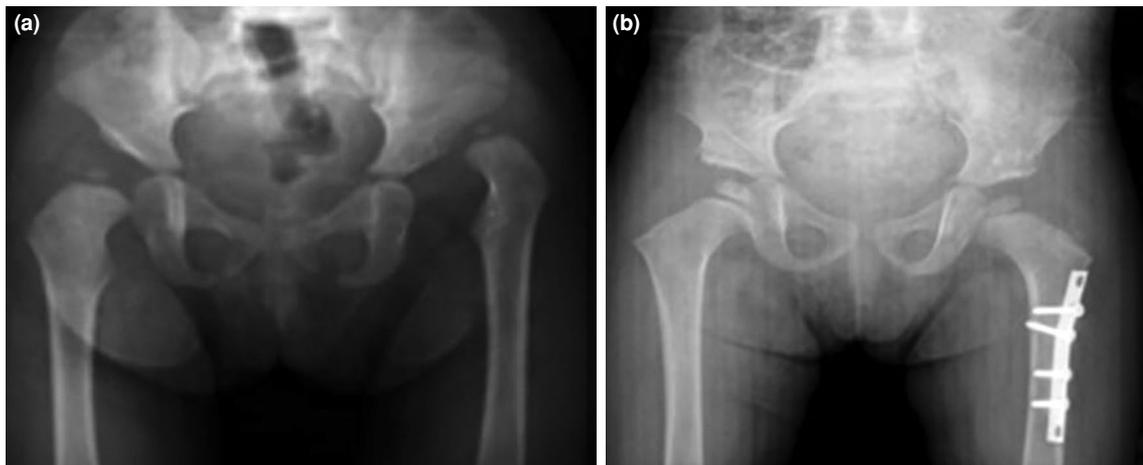
All patients were evaluated with clinical and radiological examinations at every follow-up visit according to the routine follow-up protocol of our clinic for DDH.

In clinical examinations, patient gait, Trendelenburg limping, limb-length discrepancy, limb atrophy, hip range of motion, joint stiffness, sciatica, and the femoral nerve were evaluated. Clinical outcomes were assessed using the modified McKay criteria.<sup>[10]</sup>

The acetabular index (AI) and the lateral migration index for the subluxated hip were calculated, and the femoral head position was evaluated according to Perkin's line and Shenton's line. The Severin classification was used to assess the outcome of hips.<sup>[11]</sup>



**FIGURE 2.** Intraoperative fluoroscopic views of the steps of surgery. (a) A K-wire was inserted for guidance of the osteotomy. (b) An osteotome was introduced from the lateral wall, was advanced to medial, then proceeded from ventral to dorsal to complete the osteotomy. (c) The distal part of the ilium was bent with the help of the osteotome. (d) A triangular bone graft harvested from the ilium was placed in the osteotomy site.



**FIGURE 3.** (a) Both hips of a 33-month-old female patient were treated with open reduction and Tönnis lateral acetabuloplasty at a six-month interval. There was a need for a femoral shortening osteotomy in the left hip. (b) Excellent results were obtained for the left hip after 23 months and for the right hip after 17 months of follow-up.

If present, avascular necrosis was assessed according to the Kalamchi and MacEwen classification.<sup>[12]</sup> The radiological evaluation was made by one of the authors, who was not included in the surgical treatment.

#### Statistical analysis

Data were analyzed using SPSS version 13.0 software (SPSS Inc., Chicago, IL, USA). Descriptive statistics are presented as mean  $\pm$  standard deviation, median, and minimum and maximum or frequency and percentage. Categorical data were compared using the chi-square test. The pre- and postoperative mean values were compared with the paired samples t-test. A  $p$  value of  $<0.05$  was considered statistically significant.

## RESULTS

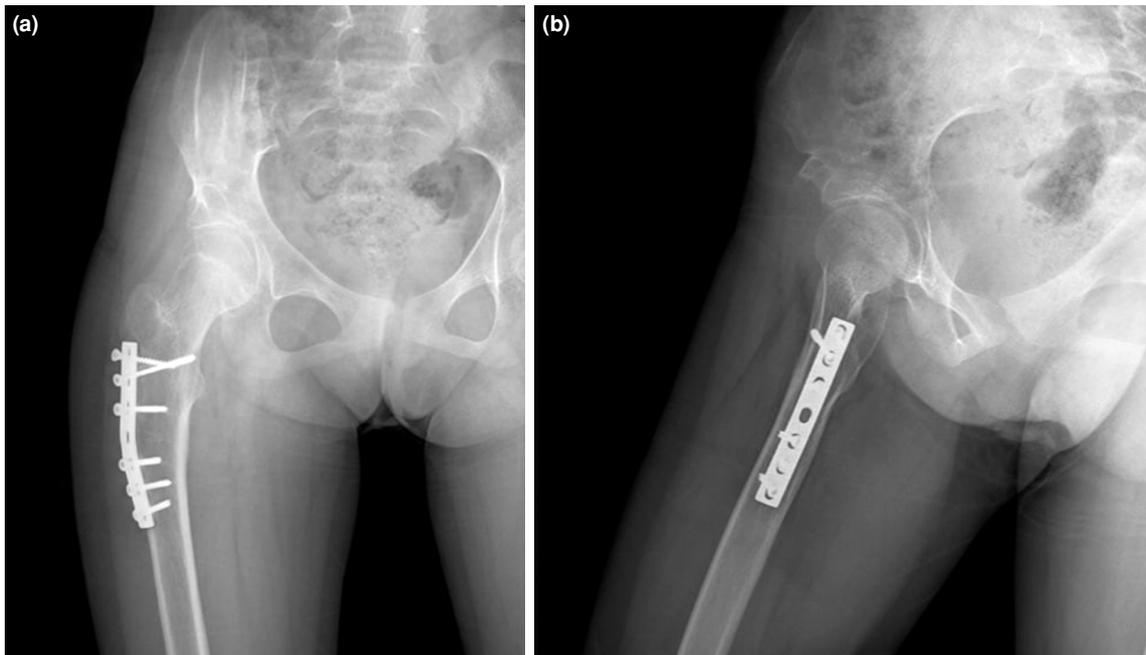
The mean follow-up period was  $27 \pm 11$  (range, 12 to 47) months. No intraoperative complications were encountered.

According to the Modified McKay criteria for DDH, 51 (77.3%) hips were classified as excellent, 11 (16.6%) as good, and 4 (6.1%) as fair (Table I). The mean AI decreased from  $36.1^\circ$  preoperatively to  $18.6^\circ$  postoperatively. The mean postoperative improvement for AI was  $17.5^\circ \pm 5$  (range,  $10^\circ$ – $33^\circ$ ). The lateral migration index improved from 89.7 to 10.6%. In the comparison of the preoperative and postoperative measurements of the AI and lateral migration index, the difference was found to be statistically significant ( $p < 0.001$ ) (Table II).

Insufficient femoral head coverage was observed in two patients. Lateralization of the femoral head, resulting in concentric reduction on abduction and internal rotation radiographs, was observed in these patients, which could be explained by the anteversion and valgus of the proximal femur. One of these patients underwent surgery for a femoral shortening by derotation-varization osteotomy,



**FIGURE 4.** (a) Preoperative anteroposterior view. (b) Early postoperative anteroposterior and (c) frog-leg views of a 132-month-old female patient.



**FIGURE 5.** (a) Anteroposterior and (b) lateral radiographs of the postoperative 47-month follow-up of the patient in Figure 3.

and the parents of the other patient refused any additional intervention.

A distal femoral fracture occurred in two patients after cast removal. Both patients were successfully treated with a short period of cast immobilization, and full recovery was obtained without any difficulties.

Avascular necrosis, premature closure of the triradiate cartilage, early reduction failure, and

infection were not observed during the follow-up period of any patients.

**DISCUSSION**

Several types of pelvic osteotomies have been described for the treatment of acetabular dysplasia. The most common procedures are incomplete transiliac acetabuloplasty with the Dega technique and the Salter complete pelvic osteotomy.<sup>[4]</sup> The Dega

**TABLE I**  
Clinical outcomes according to the modified McKay criteria for DDH

		n	%
Excellent	Stable, painless hip, no limp, negative Trendelenburg sign, and a full range of movement	51	77.3
Good	Stable, painless hip, slight limp, negative Trendelenburg sign, and a slight decrease in range of movement	11	16.6
Fair	Stable, painless hip, limp, positive Trendelenburg sign, and limitation of movement	4	6.1
Poor	Unstable or painful hip, or both; positive Trendelenburg sign	0	0

**TABLE II**  
Preoperative, early postoperative, six-month, and the last follow-up measurements of the AI and lateral migration index

	Preoperative		Early postoperative		6 <sup>th</sup> month		Last follow-up		p
	Mean	Range	Mean	Range	Mean	Range	Mean	Range	
Acetabular index (°)	36.1	22-48	21.2	11-48	19.8	9-45	18.6	9-45	<0.001
Lateral migration index (%)	89.7	10-100	12.1	3-100	10.9	1-100	10.6	1-100	<0.001

osteotomy is the procedure of choice if the dysplasia is severe, as it provides more correction to the AI, while the Salter osteotomy can provide satisfactory correction for mild to moderate dysplastic hips. It has been recommended that caution should be taken during a Salter osteotomy when combined with a femoral derotation osteotomy to avoid posterior subluxation of the femoral head.<sup>[13]</sup>

Tönnis lateral acetabuloplasty is an incomplete pericapsular iliac wing osteotomy described by Tönnis<sup>[5,9]</sup> that improves the anterior and lateral coverage of the femoral head. The main indications are patients up to six years old with residual acetabular dysplasia after surgical or conservative treatment, insufficient femoral head coverage determined during open reduction, and an AI of  $>40^\circ$ .<sup>[5,8]</sup> It can be performed alone or combined with soft tissue and bone procedures.<sup>[5,14]</sup> In the current study, adductor tenotomy and TLA were performed on 52 (79%) hips, and there was a need for additional femoral shortening and derotation-varization osteotomy in 14 (21%) hips.

Tönnis lateral acetabuloplasty is an incomplete and redirection osteotomy, which reduces the overall acetabular volume.<sup>[4,15]</sup> Tönnis lateral acetabuloplasty resembles Pemberton and Dega acetabuloplasties, as they all reduce the acetabulum diameter.<sup>[4]</sup> Although previous studies have advocated these procedures to decrease acetabular volume,<sup>[16]</sup> recent studies have shown that Dega and Pemberton acetabuloplasty increase the total volume by making the acetabulum deeper.<sup>[17,18]</sup> However, the acetabulum with open triradiate cartilage has great remodeling capacity, which could compensate for any decrease in acetabular volume. The remodeling capacity is the key to the success of the surgery.

By definition, TLA ends at the posterior bony cut, near the greater sciatic notch and almost parallel to the posterior arm of the triradiate cartilage, leaving a small bone bridge for rotation. In the Pemberton technique, the posterior bone incision is not straight. In TLA, the osteotomy starts 5 to 8 mm above the anterior iliac crest, whereas this distance is over 10 to 15 mm in Pemberton osteotomy. The osteotomy line curved in Pemberton ends in half of the posterior arm of the triradiate cartilage at the ilioischial level without reaching the greater sciatic notch. Thus, the posterior arm of the triradiate cartilage itself becomes the hinge point for rotation (Figure 1).

The incomplete nature of the osteotomy provides the advantage of eliminating the need for fixation

and a secondary procedure for implant removal. Placement of a wedge bone graft harvested from the iliac wing should be enough to secure the osteotomy.<sup>[5]</sup> It has also been suggested that contouring the iliac crest allograft enhances the stability of the osteotomy.<sup>[19]</sup> As recommended, no implant was used for fixation in the present study. An additional intervention was not required for reduction failure during the mid-term follow-up of this study.

Tönnis lateral acetabuloplasty corrects the acetabular coverage and AI depending on the flexibility of the triradiate cartilage.<sup>[6-8]</sup> In the few studies of TLA for DDH, a significant improvement in AI has been obtained.<sup>[6,7,9,14]</sup> Bayhan et al.<sup>[6]</sup> demonstrated a mean decrease of  $19.4^\circ$  (from  $40.6^\circ$  to  $21.2^\circ$ ) in the AI. In another study performed by Gunel et al.,<sup>[7]</sup> a mean correction from  $45^\circ$  to  $21^\circ$  was achieved in the AI, and the improvement continued until the final follow-up, which resulted in a mean of  $18^\circ$ . The findings of the current study support previously reported results, with a postoperative improvement in the AI with a mean of  $17.5^\circ$  (from  $36.1^\circ$  to  $18.6^\circ$ ). If the surgical technique is not applied correctly, there could be insufficient acetabular coverage and inadequate improvement in the AI.<sup>[8]</sup> In the present study, inadequate femoral head coverage was observed in two patients in the early postoperative period, indicating additional surgical intervention.

There is also concern about avascular necrosis (AVN) of the thick supraacetabular bone and intra-articular extension of the osteotomy. It has been advocated that a meticulous surgical technique is the key to avoiding such complications.<sup>[7]</sup> The main reasons for poor functional results have been reported to be coxa valga, coxa vara, conservative treatment-related AVN of the femoral head before surgery, AVN of the femoral head after surgery, and inadequate surgery. Adding to these reasons, Bruning<sup>[8]</sup> stated that varus derotation osteotomy was the most frequent cause of poor results, resulting in high malposition rates and AVN of the proximal femur. However, femoral shortening has been suggested as an additional intervention if the reduction is under tension or if it is challenging to keep the femoral head in the acetabulum after open reduction and osteotomy.<sup>[19-22]</sup> It also helps avoid pressure on the femoral head, preventing possible AVN. In the current study, femoral shortening was applied to 21% of hips. In the mid-term results of this study, no AVN or early reduction failure was determined in any patients during follow-up. Although the results are

encouraging in the present study, long-term follow-up is needed as AVN cannot be excluded for several years after treatment. According to the present study, inadequate surgery resulting in insufficient femoral head coverage could be held responsible as the leading cause of poor results.

The literature on limb shortening is controversial. However, femoral shortening should be performed when tight reduction is achieved to prevent severe pressure on the femoral head and the development of AVN. Femoral derotation osteotomy with femoral shortening is frequently required since most cases have extensive anteversion of the femoral neck.<sup>[23]</sup> In our cases, we decided to perform derotation and varization intraoperatively in the light of these data.

It has been reported that the surgical technique for the treatment of DDH could vary depending on the surgeon's experience and preference.<sup>[24]</sup> The surgeon's experience with periacetabular osteotomy is a prominent factor in improving the results and minimizing the complications.<sup>[24]</sup> Although the Salter osteotomy has been described as a simple and well-standardized procedure, better improvement of the AI with similar complication rates has been reported with TLA.<sup>[8,25]</sup> In the present study, excellent and good results have been obtained in 93.9% of patients with low complication rates.

This study constitutes one of the largest samples for TLA. However, the limitations of the study are the retrospective design and the mean follow-up time of 27 months. Further prospective studies with larger patient populations and a longer follow-up period are needed.

In conclusion, TLA must be considered as an option for the surgical treatment of DDH. The rate of excellent and good results is high, with satisfactory improvements in acetabular coverage and the AI. A meticulous surgical technique minimizes the risk of possible complications which lead to poor results. The incomplete nature of the osteotomy and placement of a wedge bone graft provides a very stable construct without fixation. Adductor tenotomy, femoral derotation, and shortening osteotomy could be performed if there is a need for additional procedures.

#### Declaration of conflicting interests

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