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ORIGINAL ARTICLE

Placement of Standard Sized Acetabular Cup Between True and False Acetabulum in Patients with Crowe III/IV Dysplasia: A Safe Option in THA Without Femoral Osteotomy

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Abstract

Introduction There is no consensus in literature on the surgical treatment of patients with Crowe type III/IV patients. Each arthroplasty procedure has its own advantages and disadvantages. In this study by placing the acetabular cup between the true and false acetabulum, we aimed to share our experience about criteria of patient selection, surgical technique, and mid-term results of THA (total hip arthroplasty) in which the risk of dislocation was minimized using a standard-sized acetabular cup.

Materials and Methods We reviewed the clinical and radiographic data of the patients with Crowe type III/IV treated by cementless THA without femoral shortening osteotomy from January 2015 to January 2020. The clinical (Harris hip score, Trendelenburg sign, limb lengths) and radiographic (AP/L hip X-ray, 3D CT) examinations before surgery; 1, 3 months and 1 year after the surgery were evaluated. All postsurgical complications were noted.

Results Among all, 268 patients met the inclusion criteria. Thirty-two patients (11.9%) were male and 236 (88.1%) were female. Mean age was 46.8 years. Mean follow-up duration was 42.4 (26–57) months. Mean Harris Hip score (HHS) was 49.7 and Trendelenburg sign was positive in all patients preoperatively. In the final evaluation, mean HHS significantly improved to 80.2 ($p < 0.005$) and none of the patients had Trendelenburg sign. Mean lengthening of the operated leg was 4.3 cm.

Conclusion Total hip arthroplasty with placement of acetabular cup between true and false acetabulum can be successfully preferred in selected patients with Crowe III/IV dysplasia.

Keywords Hip · Arthroplasty · Developmental dysplasia of hip · Acetabulum

Introduction

Total hip arthroplasty (THA) is successfully applied especially in the treatment of hip arthrosis secondary to developmental dysplasia of the hip (DDH) [1]. However, there are some problems, especially related with diversities of Crowe type III/IV patients.

Limb length discrepancy, limited elongation capacity of anatomical soft-tissue structures—especially the sciatic nerve, narrow femoral canal, increased femoral anteversion, shallow acetabulum and bone stock insufficiency, decreased joint range of motion can be considered as the main problems [2–6].

Extra small acetabular components are used especially due to insufficient bone stock, pose a high risk of dislocation [7]. On the other hand, structural bone grafting used may result in failure in the medium-long term [8]. Femoral shortening osteotomy can be technically challenging and may prolong the operation time and result in complications such as nonunion [9, 10]. Therefore, the ideal treatment method should be one in which soft-tissue tension is optimized and extremity lengths are close to equal, which can provide long-term survival. In this context, Crowe type 3/4 coxarthrosis patients who successfully underwent THA without femoral osteotomy have been reported in the literature [11]. This method will theoretically increase soft tissues and especially

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sciatic nerve tension. For this reason, we claim that if the acetabular cup is placed, more proximal maximum benefit can be obtained from the bone stock by creating optimal soft-tissue tension [12].

In this study, we aimed to report our selection criteria of patients, the surgical technique of placing the acetabular component between true and false acetabulum (where there is sufficient bone stock, the soft tissues are not strained, and the leg lengths are close to equal), and mid-term results of such procedure.

Patients and Methods

Patient Selection and Study Design

We reviewed the clinical and radiographic data of the patients with Crowe type III or IV DDH operated by the same surgeon (CI), treated by cement less THA without femoral shortening osteotomy from January 2015 and January 2020 in our institution. Arthroplasty indications were determined as pain limiting daily activities, functional issues, and leg length discrepancy.

Inclusion criteria were (a) unilateral symptomatic dysplasia of the hip, (b) patients with flexible hip on traction radiograph who has not previously undergone surgery, (c) patients where the trochanter minor does not remain above the true acetabulum level on direct X-ray, (c) patients in whom the distance between the trochanter major and minor is smaller than one femoral head size (the long ones have abduction limitation due to the impingement of trochanter major, postoperatively), (d) patients in which the ischium is not protruding (in terms of ischiofemoral impingement), and patients without neuropathic advanced degenerate spinal column. Patients with a history of any hip surgery, inflammatory joint disease, and neuromuscular insufficiency in the operated extremity were excluded. Patients who had signed informed consent about the clinical trial were included in the study.

Patient data were recorded, the clinical and radiographic examinations before surgery; 1, 3 months and 1 year after the surgery were evaluated. Patients were called for a final evaluation and assessed by Harris Hip Score (HHS) [13], presence of Trendelenburg sign was noted and limb lengths were measured. For radiological evaluation, anteroposterior (Fig. 1) and lateral hip radiography and orthoroentgenogram were used. In addition, 3D pelvis computerized tomography (CT) (Figs. 2, 3, 4, 5, 6, 7, 8) was taken, and coronal and sagittal slices were evaluated to determine acetabular structure and bone stock. All complications were noted and documented. This research has been approved by the IRB of the authors' affiliated institutions.

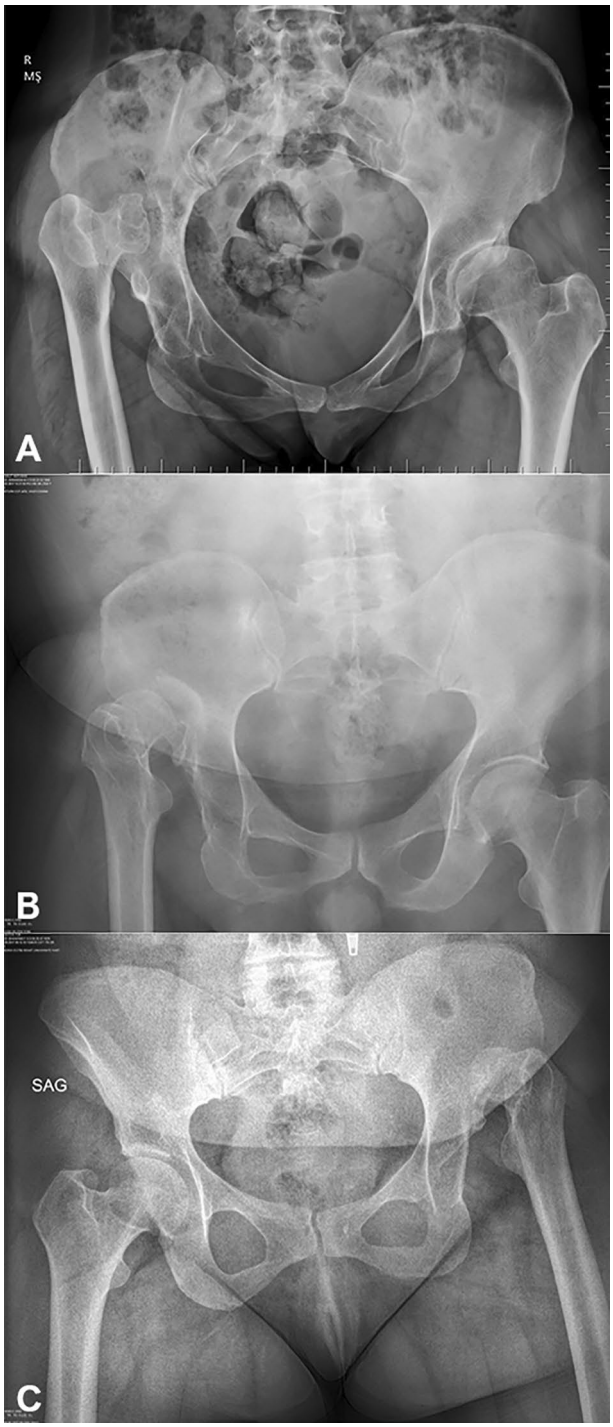

Fig. 1 Preoperative anteroposterior hip X-ray of three patients (**A**, **B**, **C**)

Data were analyzed with the SPSS software version 15.0 for Windows. Student's t test was used for variables with normal distribution. A two-tailed p value of <0.05 was considered statistically significant.

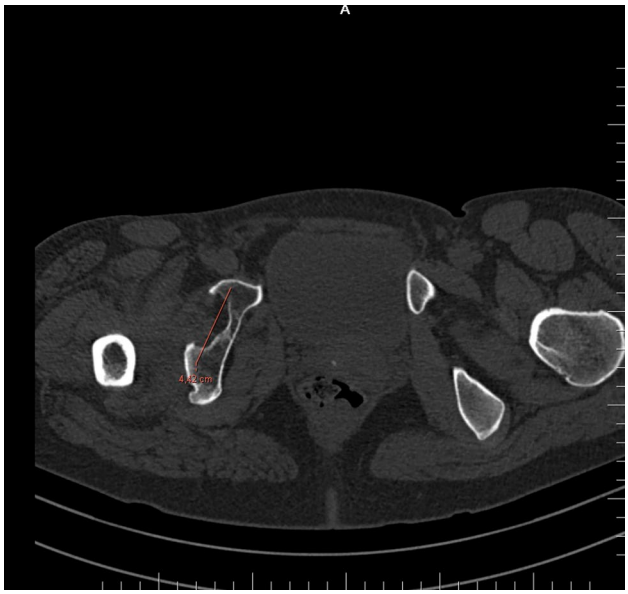

Fig. 2 Axial CT slice showing true acetabulum

Fig. 3 Axial CT slice showing superior of true acetabulum

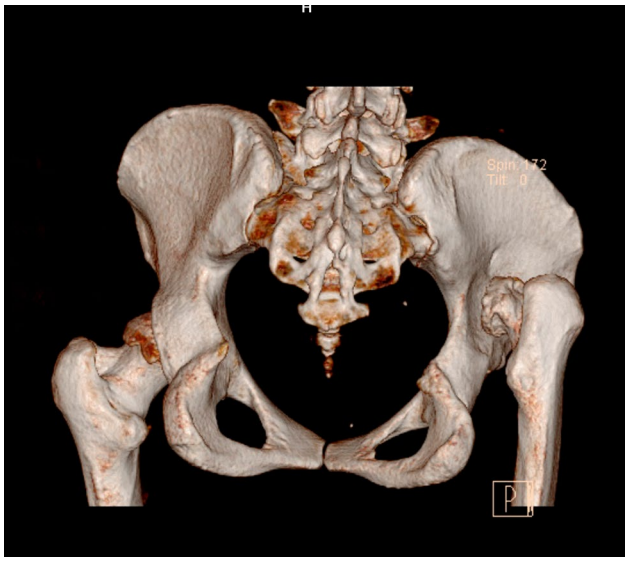

Fig. 4 Anteroposterior pelvis 3D pelvis CT

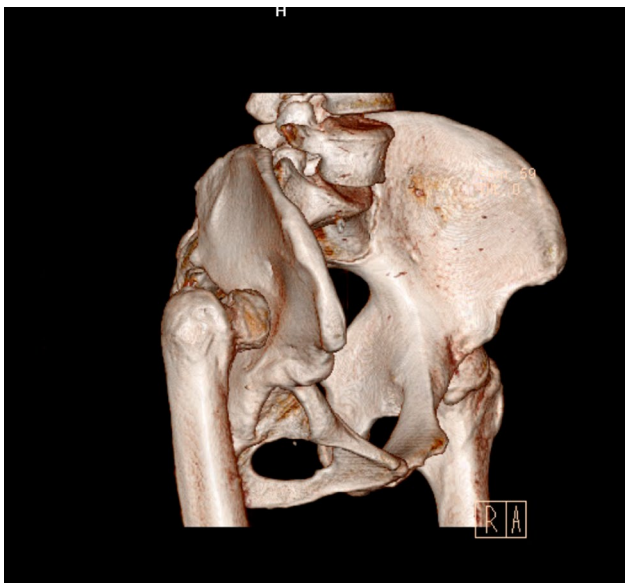

Fig. 5 Oblique pelvis 3D pelvis CT

Surgical Technique and Rehabilitation

All patients were operated by the same surgeon (CI) with the same procedure. All patients were operated under general anesthesia to obtain effective muscle relaxation and early evaluation of sciatic nerve damage. Patients were positioned in lateral decubitus position. Posterior approach was preferred in all patients. External rotators were divided and preserved for repair. Gluteus maximus tendon was released 5 cm from femur to minimize nerve compression. Joint capsule was opened and femoral neck was osteotomized. True acetabulum was reached by tracking the capsule and true acetabulum was revealed. The protruding trochanter minor was osteotomized to prevent impingement, and therefore the iliopsoas tendon, which we protect in patients with subtrochanteric shortening osteotomy, is tenotomized in these cases, in order not to interfere with adequate lengthening. Anteroinferior capsule was loosened, if necessary. The acetabular cup (Trilogy Cup, Zimmer, Warsaw, Indiana, USA) was placed by

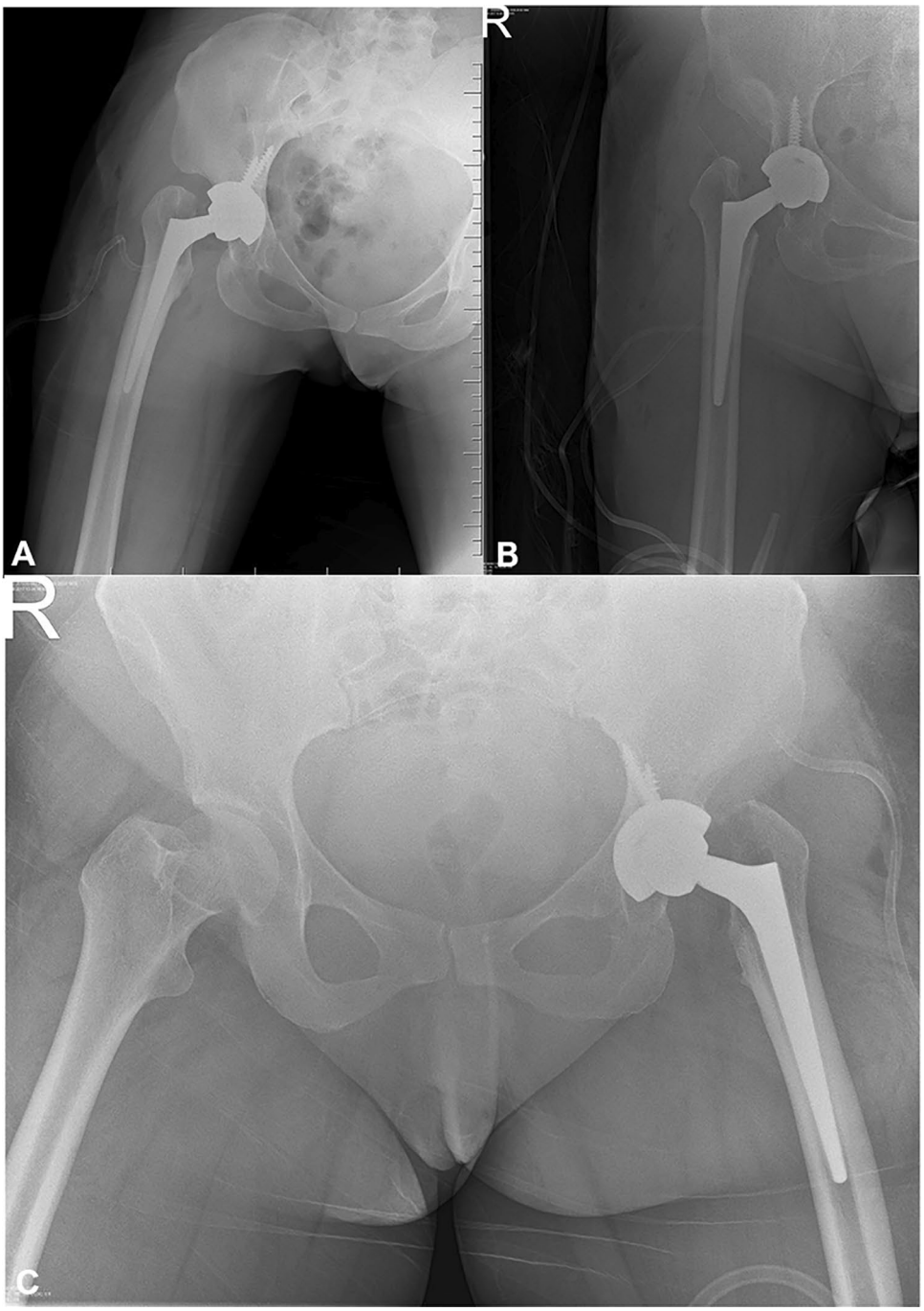

Fig. 6 Early postoperative anteroposterior hip X-ray of three patients (**A**, **B**, **C**)

carving the full apex of the true acetabulum, so that it was compressed between the spina iliaca anterior inferior (SIAI) and ischium, which is the longest diameter, and primary stability was ensured by 2 screws from the cup to the posterior column and anteriorly (Figs. 9, 10, 11). The posterior screw should generally not be less than 35 mm. After proximal femur reaming, cement less femoral stem (Wagner Cone Prosthesis Hip Stem, Zimmer, USA) with lateral offset was placed to all patients to obtain optimal abductor tension without excessive leg length increase. Femoral stems should have a low collodiaphyseal angle because of the risk of impingement and to reduce the joint. Reduction was performed on the hip with acetabular liner and femoral head, its stability was checked, and no problems were observed. Gluteus medius and minimus must be preserved. Posterior part of trochanter major that can result impingement in external rotation should be osteotomized, if necessary, while medius and minimus attachment points should be preserved. External rotators were not usually sutured, because they were short and the offset was

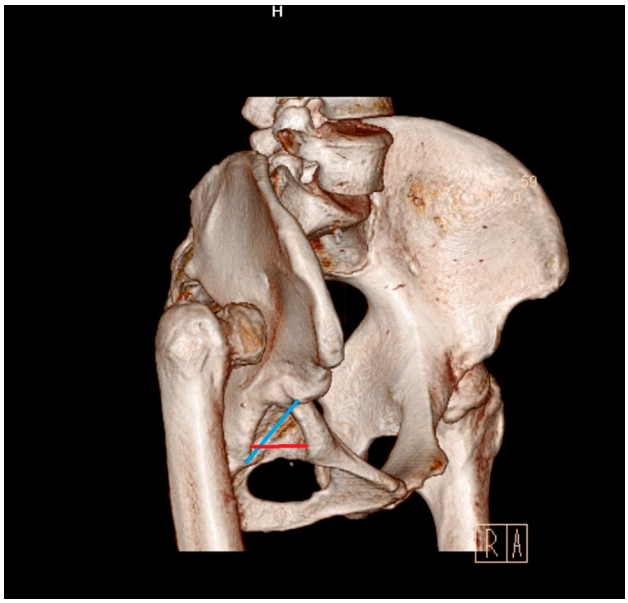

Fig. 7 Oblique pelvis 3D pelvis CT. Red line shows axial diameter of true acetabulum. Blue line shows the length between ischium and SIAI

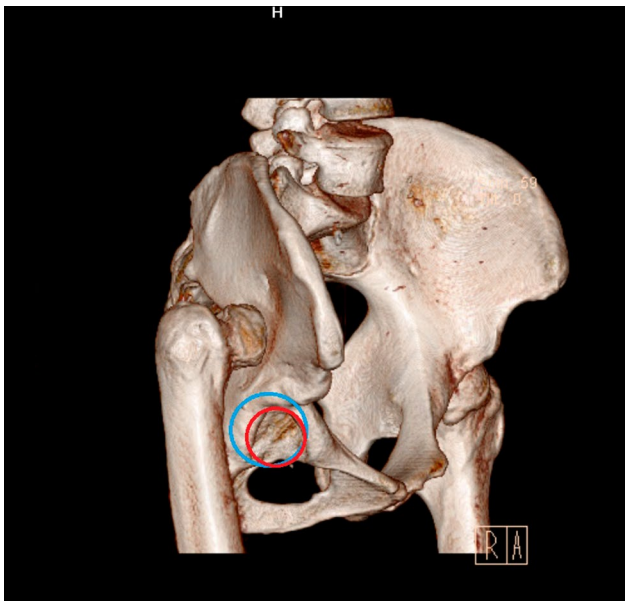

Fig. 8 Oblique pelvis 3D pelvis CT. Red line shows the place of acetabular cup in standard technique (true acetabulum). Blue line shows the place of acetabular cup in described technique (the area between ischium and SIAI)

increased by surgery, but in appropriate cases, they can be sutured in patients with preoperative high offsets.

In the postoperative period, the patients were mobilized with tolerable loads on the next day of the operation. Anti-rotation boot was used for 3 weeks at night to control involuntary and excessive motions. Routine

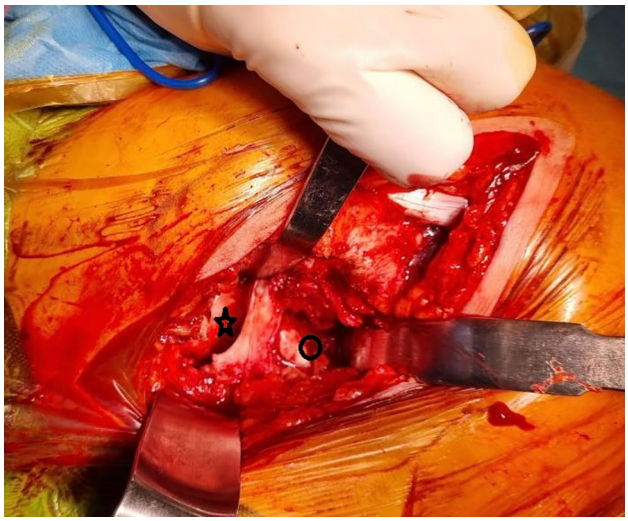

Fig. 9 Peroperative image of the patient showing true and false acetabulum. *Star*: false acetabulum, *circle*: true acetabulum

Fig. 10 Peroperative image of the patient showing the position of acetabular component. *Star*: spina iliaca anterior inferior, *circle*: ischial tuberosity

anteroposterior and lateral hip radiography were taken (Fig. 6).

Results

Among all, 268 patients met the inclusion criteria. Thirty two (11.9%) were male, 236 (88.1%) were female. Mean age was 46.8 (32–76) years. Mean follow-up duration was 42.4 (26–57) months.

Mean HHS significantly improved ($p < 0.005$) from mean 49.7 (45–63) preoperatively to 80.2 (74–95) in the final evaluation. Trendelenburg sign was positive in all patients

Fig. 11 Peroperative image of the patient showing the position of acetabular component after implantation

preoperatively. In the final evaluation, none of the patients had Trendelenburg sign. Mean duration of surgery was 53 min (43–68). Mean lengthening of the operated leg was 4.3 cm (3.5–6.1).

44 mm sized acetabular cups and 26 mm heads were used in 261 (97.3%) patients; 42 mm cups and 22 mm heads were used in 7 (2.7%) patients. In postoperative 1 month follow-up, one patient with 42 mm cup and 22 mm head (0.37%) had dislocation. Open reduction was successfully performed in this patient and no recurrence of dislocation was observed. Sciatic paresthesia was observed in 4 patients (1.4%) and all of them resolved in a mean of 6 months period (2–8). Acetabular protrusion was observed in only one patient (0.37%) and acetabular revision with cage was performed. Due to insufficient bone stock, primary acetabular cages were used in two patients (0.74%).

Since even the smallest femoral component was too big for the femoral medulla in one patient (0.37%), we created a fissure by forcing the stem in a controlled manner and fixed it with a single Dall miles cable. Except for this controlled osteotomy on the femoral side, 7 patients (2.61%) had a proximal fissure connected to the Wagner cone, but adequate fixation was achieved with a single Dall miles cable, weight-bearing was delayed for 3 weeks in these patients, and the others gave as much weight as they could tolerate within 24 h.

Discussion

In this article, we aimed to determine the characteristics of patients with Crowe type III/IV suitable for the operation without shortening and with inserting larger cups than expected. In addition, based on our case experience, we aimed to identify the patients for whom this technique was most beneficial. Various alternative surgical techniques have been developed in the treatment of patients with Crowe type 3 and 4 coxarthrosis, which is one of the most difficult conditions [1–7]. To overcome these challenging issues, some methods like femoral shortening osteotomy, using extra small acetabular cups, structural bone grafting were proposed in the literature [8, 10, 12]. However, each method has its own unique problems, risks, and complications.

Due to the lack of sufficient bone stock, loosening is common in the medium–long term in high hip center THA cases [7, 14]. For this reason, selecting the appropriate size of acetabular cup is important [12]. In this case, for the hypoplasic acetabulum, smaller acetabular cup has to be placed. At the same time, femoral shortening osteotomy is used to prevent neurovascular problems. Liu et al. [15] reported that total hip arthroplasty with femoral shortening osteotomy can greatly improve hip joint function and relieve pain without significant complications. On the other hand, one of the most important disadvantages of the osteotomy is the risk of fracture or nonunion. Furthermore, recurrent dislocations may occur, and overall, the rate of complications has been reported to range from approximately 15–40% [16, 17]. Additionally, subtrochanteric shortening osteotomy and/or additional fixations used in osteotomy fixation increase the surgical time, bleeding, infection risk, and prolong of the rehabilitation period. All these disadvantages of subtrochanteric osteotomy can be potentially avoided by our described technique. We cannot measure this length in the axial CT section (Figs. 2, 3); however, in 3D CT, it can be clearly seen that a larger cup can be placed and compressed between the SIAI and the ischium. Therefore, although the real acetabulum suggests to place a larger cup in the axial section, in the technique we mentioned, we were able to place the cup of the same/larger diameter in all cases (Figs. 7, 8). The advantage of this technique is that it is possible to place the acetabulum both more posteriorly and more proximal from its real location. In this way, it is easier to reduce the joint, which is usually dislocated posterosuperior, and it is possible to reduce the tension on the sciatica even more than the classical technique.

Successful results were obtained in similar patient groups without femoral osteotomy, which is one of the alternative methods aimed at excluding these complications. Tahta et al. [11] reported successful results in selected cases. Serious neurovascular complications have also been reported in THA patients who underwent in-contrast, femoral shortening without osteotomy. Although Eggli et al. [18] reported that neurological complications are related to direct damage during surgery rather than lengthening of the leg, the prevailing opinion in the literature is that it is due to excessive leg lengthening. Therefore, existing neurovascular risks limit this alternative. Additionally, we think that this procedure

may technically problematic in patients with higher levels of trochanter. We speculate that it may be difficult or not possible to reduce the hip joint due to high tension of soft tissues. We conclude that, since no shortening osteotomy is performed, the leg length can be lengthened more, the return to social life is shorter, and the patients have a much higher chance of walking, especially aesthetically. We observed that patients whose legs are acutely lengthened adapt to social life very quickly, and we do not apply a different rehabilitation than classical total hip arthroplasty. A 125-degree neck shaft angle Wagner cone with lateral offset was used routinely; care was taken not to use a negative head in order not to increase the risk of impingement [19]. When the joint could not be reduced due to tension, instead of using a smaller (−3.5) head, a controlled fissure was made if the stem was necessary, and reduction was achieved by burying the femur more in the medullary canal. Because of its sharp edges, the Wagner cone should be placed more gently and with smaller hammer blows than other stems; otherwise, fissure development is easier than other stems. In fact, we use one size smaller than the classic hammer to reduce this risk. Additionally, while iliopsoas tenotomy is generally not required in subtrochanteric shortening osteotomy, but it is routinely required in cases without shortening.

No additional action was taken for hip flexion contractures up to 45° due to tension after reduction. It was observed that the patient recovered within 3 days before discharge. In more contractures, the tension was reduced by applying a pie-crust procedure to the fascia anteriorly from the incision.

Zha et al. [20] reported that the rate of medial protrusion of <60% may be necessary to obtain excellent clinical and radiographic mid-term results in patients with DDH treated with THA. Therefore, we applied the medial protrusion technique in most of the patients to fix a screw with a length of at least 30 mm in the appropriate direction in the thinner than normal iliac bone and to place the cup press-fit between the ischium and the SIAI, and to obtain sufficient superior bone coverage. However, we were very careful not to disturb the acetabular integrity by reverse reamerization in patients with poor bone quality and to ensure that the diameter of the defect in the center of the acetabulum should not be larger than 2 cm. In their cadaveric study, Martin et al. interpreted that osteoporotic patients with a medial wall defect after THA may be susceptible to fracture during activities of daily living. They advocated that protected weight bearing with an assistive device may be reasonable to minimize fall risk until cup ingrowth is achieved [21]. Therefore, we spent the longest part of the total surgical time cleaning the soft tissues of the acetabulum and its surroundings, so that they could be seen clearly. In this way, it became much easier to determine the ideal position of the cup, to determine the exact location of the screws, and to reamerize the most suitable location. The placement of the cup although is between the true and false acetabulum, the cup is more closer to the true dysplastic acetabulum (slightly higher hip center) than the false acetabulum (high hip center). In all patients, we achieved sufficient stability with primary press-fit compression of the acetabular cup between the SIAI and the ischium and two iliac bone screws. We did not need to put superior graft support in any of the patients.

De Fine et al. reported that a hazardous lengthening threshold cannot be surely identified. They stated that DDH and previous hip surgeries are the most frequently recognized risk factors. They reported that rate of full nerve function restoration approximates two-thirds of the cases, independently of the extent of initial neural damage [22]. However, we did not encounter any sciatic nerve damage in cases where we did not detect excessive tension in the sciatic nerve with direct palpation after reduction. We encountered paresthesia in the form of burning in the feet and legs up to the 8th week in two patients in whom we detected moderate tension in the sciatic nerve after reduction. At the end of 3 months, the neurological symptoms completely improved in the patients. Therefore, tension in the sciatic nerve after reduction during surgery may be a marker for the risk of postsurgical nerve damage. In the presence of an over-tensioned sciatic nerve after reduction, a solution should be sought by shortening the leg length a little (such as impacting the stem more toward into the femoral canal/exchanging with a smaller stem, etc.) in a way that will reduce the tension. It should be noted that shortening osteotomy could always be applied when necessary.

The improvement or development of pelvic obliquity in patients with DDH should be well documented [23]. Zhang et al. [24] found that PO changed significantly in the first year after THA surgery and the changing value of PO angle slowed down substantially during the first 2 years after THA. We found that PO improved within 3 months. While especially young and patients with flexible deformity spent this first 3 months almost asymptomatically, low back pain and paresthesia on the elongated side especially in the first 3 months after surgery in elderly patients with degenerate curvature were observed in our series. The paresthesia we observed in four patients completely recovered after mean of 6 months. Therefore, patients with degenerated spinal curvature before surgery and patients with tension in the sciatic nerve after reduction during surgery can be considered a risk factor for the incidence of postoperative neurologic findings. We think that in these patients, more careful and limited lengthening should be considered as a precaution.

In the light of all information shared above, we conclude that the acetabular cup can be placed between the true and false acetabulum. We conclude also that, when we compress the acetabular cup between the SIAI and ischium, we can use the larger-in-size cup without the need for additional

fixation. In this case, instead of measuring the anterior–posterior diameter, we recommend measurements preoperatively in CT sections. Compared to the anterior posterior diameter of the real acetabulum, the anterior posterior diameter of the acetabular roof is shorter in this technique; therefore, larger standard-sized acetabular cups can be used.

While following this technique, it is suggested to follow the inclusion criteria strictly, till further prospective or case-controlled studies are available to compare THA with or without subtrochanteric osteotomy techniques.

The major limitations of this study are the limited number of patients, limited duration of follow-up, and the retrospective design. The final outcome scores were only compared with preoperative data. However, we think that it is very difficult to create homogeneous groups that can be compared with other possible methods due to the strict patient selection criteria. Further prospective studies are required with larger patient series and control groups with longer follow-up periods to confirm the findings of this study.

In conclusion, placement of acetabular cup between true and false acetabulum can be successfully preferred in selected patients with Crowe III/IV dysplasia.

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Declarations

Conflict of Interests The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Ethical Standard Statement This article does not contain any studies with human or animal subjects performed by the any of the authors.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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