ACTA ORTHOPAEDICA et TRAUMATOLOGICA TURCICA
www.aott.org.tr

Research Article

A new modification of the Trapdoor Procedure without surgical hip dislocation in the management of patients with osteonecrosis of the femoral head: A retrospective case series

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ARTICLE INFO

Article history:
Submitted May 23, 2019
Received in revised form
January 13, 2021
Last revision received
April 12, 2021
Accepted May 10, 2020

Keywords:
Trapdoor procedure
Hip
Femoral head
Osteonecrosis
Modification
Surgical hip dislocation

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ABSTRACT

Objective: The aim of this paper was to investigate the mid-term results of a modified Trapdoor procedure that can allow grafting of the femoral head without surgical hip dislocation in the management of patients with osteonecrosis of the femoral head.

Methods: 16 hips of 12 patients (7 female, 5 male; mean age = 38.5 ± 10.7) surgically treated by the new modification of Trapdoor procedure were retrospectively reviewed and included in the study. Based on the Association Research Circulation Osseous (ARCO) classification system, seven hips (43.7%) were stage 2, and nine hips (56.3%) were stage 3. The mean follow-up was 48.4 ± 25.7 months (range = 12-107). All the patients were evaluated postoperatively at the 6th week, 3rd month, 6th month, 1st year, and annually thereafter until their final follow-up. Clinical assessment was performed using the Harris Hip scoring (HHS) system, Non-Arthritic Hip score (NAHS) and Visual analogue pain scale (VAS). At the final follow-up, degenerative changes were examined according to the Kellgren-Lawrence scale.

Results: The mean HHS increased from 53.43 ± 9.0 (range = 36-67) preoperatively to 83.81 ± 6.1 (range = 72-95) at the final follow-up ($P < 0,001$). The mean NAHS increased from 51.5 ± 8.2 (range = 36.25-61.25) preoperatively to 86 ± 3.2 (range = 81.5-90) ($P < 0,001$) at the final follow-up. The mean preoperative VAS decreased from 7.85 ± 0.9 (range = 6.45-9.5) to 3.05 ± 0.9 (range = 1.6-5.2) ($P < 0,001$) at the final follow-up. 13 hips demonstrated 80 and higher scores according to HHS. In the remaining three hips (ARCO stage 3), the mean postoperative HHS, NAHS, and VAS scores were 76, 82, and 3,2 respectively. According to Kellgren-Lawrence scale, three hips (18,75%) were determined as grade 0, 10 hips (62.5%) as grade 1, and 3 hips (18.75%) as grade 2.

Conclusion: The Modified Trapdoor procedure without surgical hip dislocation seems to be a suitable technique with favorable clinical outcomes for the treatment of ARCO stage 2 and stage 3 osteonecrosis of the femoral head.

Level of Evidence: Level IV, Therapeutic Study

Introduction

Hip osteonecrosis is a complex and often debilitating disease. If left untreated, it can cause femoral head collapse and mechanical failure of the hip joint that eventually leads to secondary osteoarthritis. Most patients are between second and fourth decades of life, and relatively long-life expectancy increases failure rate of hip arthroplasty.[1,2] Therefore, treatment of osteonecrosis should focus on preservation or restoration of the femoral head blood supply and structural support within the femoral head as long as possible, especially in young patients.[1-5]

Non-vascularized bone grafting techniques have been demonstrated to be viable treatment options for patients who have pre-collapse or early post-collapse disease, where the articular surface is intact or with less than 2 mm of depression of the femoral head.[6,7] The grafting can be performed through a core decompression tract (Phemister technique),[8] a window made in the femoral neck or head–neck junction (lightbulb technique)[9] or a window made in the articular surface of the femoral head (trapdoor technique).[5] The theory behind these techniques is debridement of weak necrotic bone down to the good viable bleeding bone and providing a scaffold for the formation of new bone, thus providing stability to the femoral head.[6,7]

Bone grafting through a so-called trapdoor in the articular cartilage and subchondral bone has been used to treat hip osteonecrosis secondary to various etiologies.[4,5,10] It is performed through an anterior or anterolateral approaches with an arthrotomy to dislocate the hip joint and allows a wide exposure of the femoral head. However, it is a relatively more invasive surgery than other bone-preserving procedures and can sometimes be associated with certain complications.[11]

There is little information in the literature about using this technique without performing surgical hip dislocation and trochanteric osteotomy.[12] We described a modification of the trapdoor procedure, which was applied through a window made at the anterior and non-

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Cite this article as: *Akman B, Güven M, Kadıoğlu B, et al. A new modification of the Trapdoor Procedure without surgical hip dislocation in the management of patients with osteonecrosis of the femoral head: A retrospective case series. Acta Orthop Traumatol Turc 2021; 55(4): 299–305.*

DOI: 10.5152/j.aott.2021.19276

weightbearing part of the femoral head without performing surgical hip dislocation. We aimed to answer whether this technique effectively eliminated further surgical treatment compared to those reported in studies using the trapdoor technique with performing surgical hip dislocation. Our hypothesis was that the modified trapdoor procedure without surgical dislocation is a technique with a low surgical complication rate that positively contributes to postoperative functional outcomes in the surgical treatment of the femoral head osteonecrosis.

Materials and Methods

This study was approved by the Ethics Committee for Scientific Research of Medeniyet University Göztepe Training and Research Hospital with the approval number of 2020/0562. Medical records of patients with femoral head osteonecrosis treated in the Department of orthopaedic surgery between March 2007 and September 2014 were retrospectively reviewed. Patients who were operated with a technique other than modified trapdoor procedure, patients over 60 years old and under 18 years old, patients with less than one year follow-up period and patients who had undergone previous hip or ipsilateral lower extremity surgery were excluded from the study. Regardless of risk factors, patients were included in the study. Patients were included in this study regardless of etiologic factor.

Age, gender, body mass indexes, etiological risk factors and hip joints with avascular necrosis of patients were noted. ARCO classification was used to classify the avascular necrosis stages of the patients[13] (Table 1).

A diagnosis of femoral head osteonecrosis was made based on clinical history and appearance on anteroposterior and frog-leg pelvis radiographs as well as on magnetic resonance imaging (MRI) scans (Figure 1). All radiologic evaluations were performed by one of the study authors, who were blinded to study design.

The combined necrotic angle measurement from MRI scans was used to predict the lesions' size and the subsequent risk of femoral head collapse.[14] We measured the arc of the femoral surface involved by necrosis on midcoronal and midsagittal MRI scans and then calculated the sum of the angles

All operations were performed under general anesthesia by the same surgical team (first two authors; BA and MG) through an anterior ilioinguinal approach when patients lay in the supine position (Figure 2**a**). The interval between tensor fascia latae and sartorius muscle was identified. Dissection was extended proximally to expose the lateral surface of the iliac bone. Rectus femoris muscle was not incised from attachment to the upper part of the acetabular rim. It was retracted medially (Figure 2**b**). Joint capsule was then opened with a T-shaped incision, and the anterior part of the femoral head cartilage was inspected in situ. The hip joint was not dislocated from the acetabulum during the procedure. Using a microoscillating saw and osteotomes, an approximate 1.5 cm length and width quadrangular window

Table 1. Classification System of the Association Research Circulation Osseous

Stage	Findings	Techniques	Subclassification	Quantitation
0	None	Radiography, computed tomography, scintigraphy magnetic resonance imaging	No	No
1	Radiography and computed tomography normal. At least one of the other techniques is positive	Scintigraphy and magnetic resonance imaging	Location of lesion Medial, Central and Lateral	Area of involvement (percentage) A: Minimal B: Moderate C: Extensive Length of cresent A: <15% B: 15-30% C: >30 Surface collapse A: <15% and <2 mm B: 15%-30% and 2-4 mm C: >30% and >4 mm
2	Sclerosis, osteolysis	Radiography, computed tomography, scintigraphy magnetic resonance imaging	Same as stage 1	Same as stage 1
3	Crescent sign and/or early flattening of the surface	Radiography, computed tomography	Same as stage 1	Same as stage 1
4	Osteoarthritis, acetabular changes, joint destruction	Radiography only	No	No

(trapdoor) was elevated from the anterior part of the femoral head (Figure 2**c**). The window segment was preserved and stored in regular saline-wrapped gauze for replacement at the end of the procedure. All visible dead bone was then removed using curettage and power burrs until a bleeding surface was encountered at the base of the cavity (Figure 2**d**). Accidental head penetration with burr was avoided. Bone graft, consisting of autogenous cancellous bone, was taken from the iliac crest using the same skin incision (Figure 3**a**). The cavity was filled with cancellous graft (Figure 3**b**), the trapdoor was replaced without fixation (Figure 3. **c-e.**) and the joint capsule was tightly closed over it. Allogenic graft material was not used in any of the cases. The skin incision was closed in a standard fashion.

All patients used low molecular weight heparin during the first month after the operation. Active and passive ranges of motion exercises with isometric quadriceps strengthening were started on the second day postoperatively. All patients were maintained at toe-touch weight-bearing with two crutches or a walker for 6 weeks. Then, patients were mobilized with two crutches for another 6 weeks with up to 50% weight-bearing. Full weight-bearing without support was allowed at 12th week. All patients followed a strict rehabilitation program after this period for muscle strengthening.

Patients were evaluated postoperatively at 6th week, 3rd month, 6th month, 1st year, and annually thereafter until final follow-up (Figure 4). Clinical assessment was performed using Harris Hip Scoring (HHS) system,[15] Non-Arthritic Hip Score (NAHS)[16] and Visual Analogue Pain Scale (VAS).[17] HHS with 90 to 100 points was accepted as an excellent

HIGHLIGHTS

- Trapdoor procedure is performed through an anterior or anterolateral approach with an arthrotomy to dislocate the hip joint and allows wide exposure of the femoral head.
- The modified trapdoor technique allows grafting of the femoral head without hip dislocation. Thus, the potential complications of surgical hip dislocation can be prevented.
- This technique is a safe and effective surgical option for the treatment of ARCO stage 2 and stage 3 femoral head osteonecrosis.

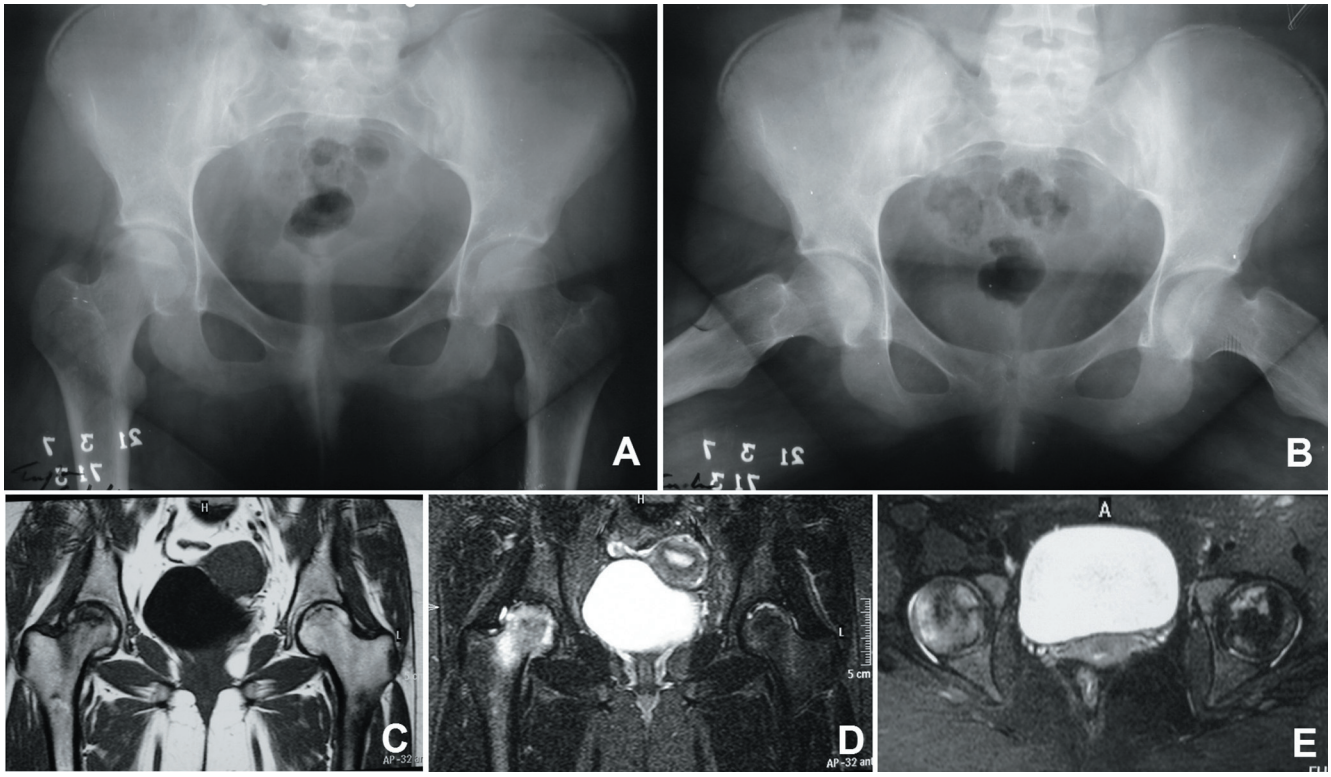

Figure 1. A-E. Anteroposterior (a) and frog-leg (b) radiographs of the pelvis of an 18-year-old female patient (6th patient in Table 1) before the operation show minimal lucent and sclerotic lesions on the right hip with no radiographic changes on the left hip. T1-weighted coronal MRI scan (c) demonstrates low signal intensity in the superior weight-bearing area of the right femoral head. There is also a low signal intensity rim in the proximal aspect of the left femoral head. T2-weighted coronal (d) and axial (e) MRI scans show high signal intensity of the entire right proximal femur and also high signal intensity line in the superior part of the left femoral head.

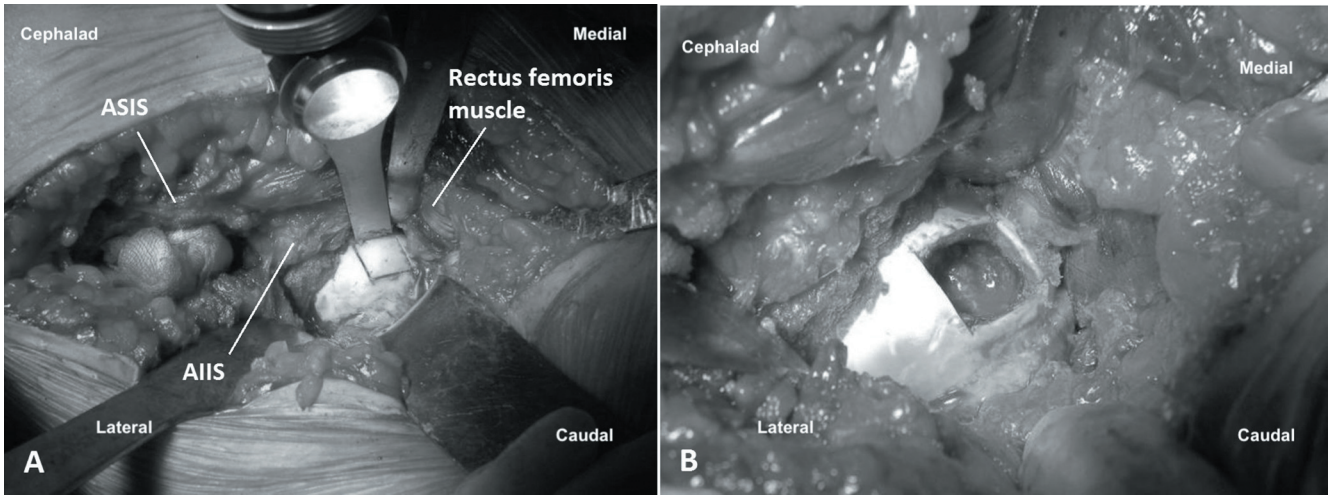

Figure 2. A, B. (A) Rectus femoris muscle is not incised from the attachment. Using a microoscillating saw, a trapdoor segment is lifted from the anterior and non-weightbearing part of the femoral head without dislocating the hip joint. (B) All visible dead bone is removed.

result, 80 to 89 as good, 70 to 79 as fair, and less than 70 as a poor result. Clinical success was defined as an HHS of 80 points or more. Degenerative changes were evaluated on plain radiographs according to Kellgren–Lawrence scale[18] at final follow-up and the hips were classified from grade 0 (no visible features of osteoarthritis) to grade 4 (joint space impaired severely, cysts and sclerosis of the subchondral bone). Treatment was defined as failed in patients with an HHS of less than 80 points or who had subsequent surgery.

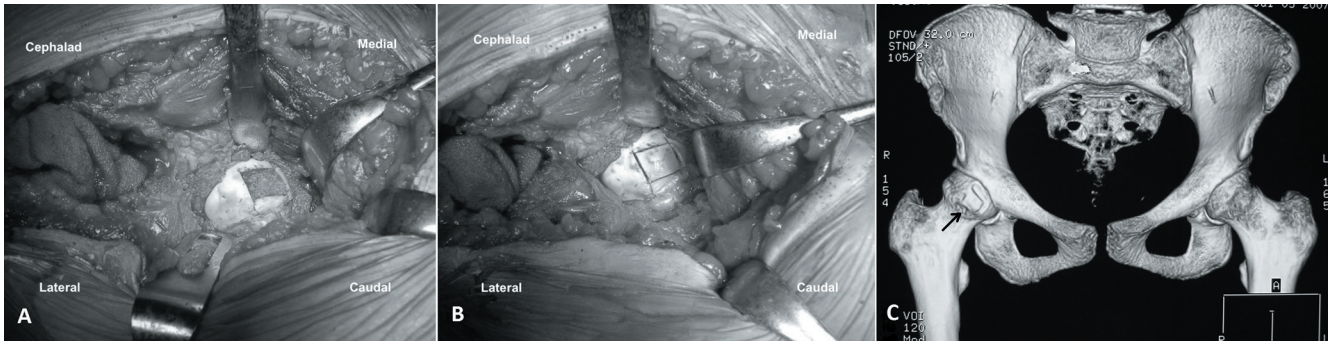

Figure 3. A-C. (a and b) Cancellous bone graft is placed and trapdoor segment is replaced without fixation. (c Postoperative 3D CT image shows the trapdoor segment (black arrow) which is located at the anterior and non-weightbearing surface of the femoral head.

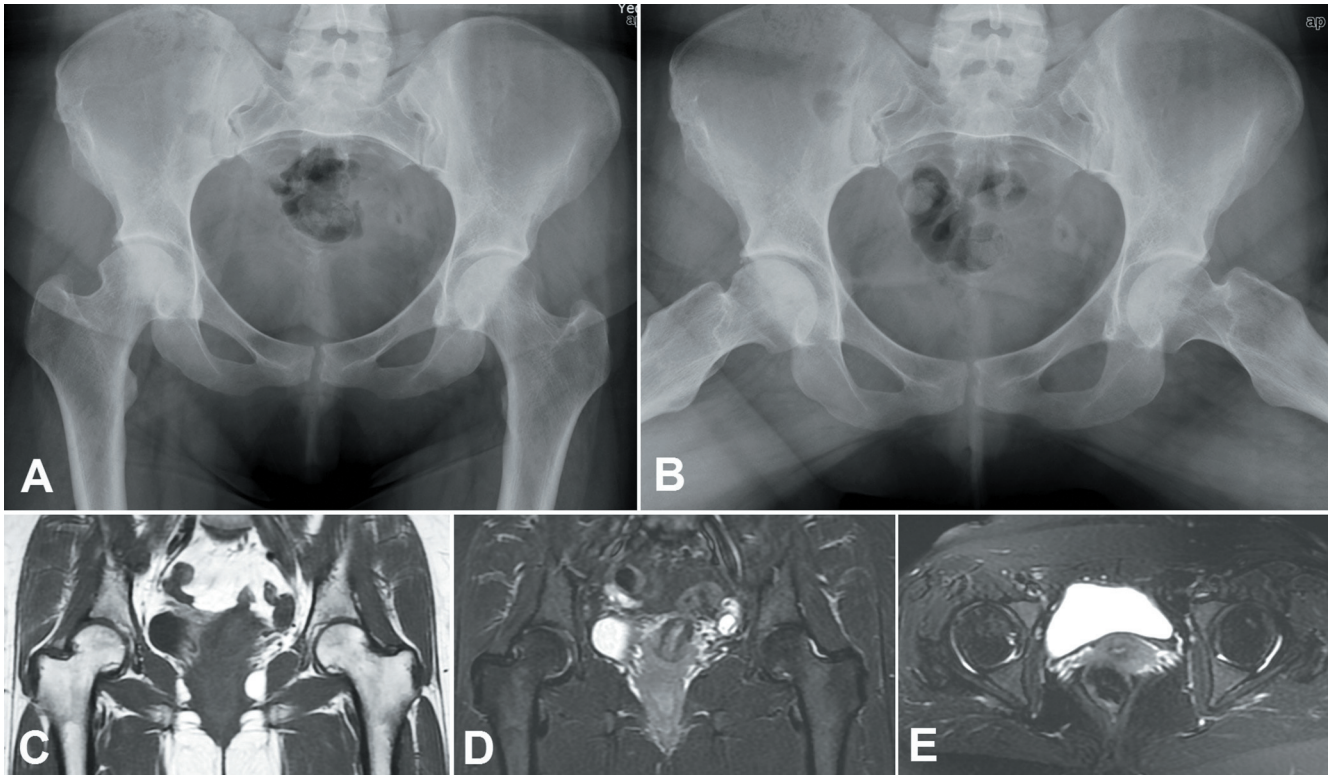

Figure 4. A-E. Radiographic evaluation of the same patient at 8th year postoperatively. On the anteroposterior (a) and frog-leg (b) radiographs of the pelvis, there is no evidence of joint space narrowing with minimal degenerative changes including osteophytes at the lateral part of the femoral head and superolateral acetabular rim. MRI scans of the pelvis (c-e) demonstrate complete reversal of the signal abnormalities. The normal contours of the femoral heads are well preserved.

Statistical analysis

The statistical analysis was performed with the IBM SPSS Statistics 20 for Mac (Statistical Package for Social Sciences for Mac ver.20, IBM SPSS Corp, Armonk, NY, USA). Wilcoxon Signed Ranks Test was used to compare pre-and post-operative scores. $P < 0.05$ was considered as statistically significant.

Post-hoc power analysis was performed using the G-power 3.1 statistical software. Cohen's effect size *d* (0.8), alpha (0.05) and sample size (n = 16) values were used to calculate the statistical power (1 − β) of this study. The statistical power of this study was calculated as 0.84.

Results

A total of 16 operations were evaluated retrospectively, which were applied to 12 patients (seven female and five male). The mean age of the patients at the time of surgery was 38.5 ± 10.7 years (range: 30-60) and the mean body mass index was 27.2 ± 1.9 kg/m^2 (range: 23.5-30.1). Four patients (25%) had bilateral femoral head osteonecrosis. None of them had been operated simultaneously and the average time interval between the two operations was 4.5 months (range: 3-6).

As etiological risk factors, we identified drug addiction in one patient (two hips; 12.5%), corticosteroid usage in four patients (six hips;

Table 2. Patient Demographics and Study Data

n	Age/gender	Side of ON	Etiologic factors	BMI (kg/m²)	Follow-up (months)	Stage of ON	can	NAHS (pre)	NAHS (post)	HHS (pre)	HHS (post)	VAS (pre)	VAS (post)	Kellgren–Lawrence scale
1	30/male	Bilateral	Drug addiction	24.7	72	Both Stage 3	200°	45	85	48	81	7.25	3.2	Grade 1
							215°	36.2	82.5	36	80	8.2	2.5	Grade 1
2	48/male	Left	Corticosteroid	27.4	43	Stage 3	204°	55	87.5	52	94	8.74	3	Grade 1
3	47/male	Right	Idiopathic	25.4	33	Stage 2	184°	58.7	88.7	61	86	7.34	2.3	Grade 0
4	60/male	Left	Idiopathic	28	12	Stage 3	220°	37.5	82.5	45	72	9	4	Grade 2
5	34/male	Bilateral	Corticosteroid	23.5	12	Stage 2	190°	52.5	83.7	50	84	7	3.1	Grade 1
						Stage 3	210°	52.5	81.5	50	78	6.45	2.15	Grade 2
6	18/female	Right	Cushing disease	29	107	Stage 2	190°	52.5	90	50	92	8.25	2	Grade 1
7	30/female	Bilateral	Corticosteroid	26.4	43	Stage 2	180°	58.7	88.7	66	84	7.1	1.6	Grade 1
						Stage 3	205°	55	82.2	56	78	8.75	3.5	Grade 2
8	38/female	Right	Idiopathic	26.9	43	Stage 2	186°	61.2	90	67	95	6.8	2.45	Grade 0
9	40/female	Left	Idiopathic	28.6	60	Stage 3	208°	48.7	86.2	50	82	9.5	3.75	Grade 1
10	33/female	Bilateral	Cushing disease	29	42	Stage 2	200°	57.5	87.5	60	86	7	4.1	Grade 0
						Stage 3	218°	37.5	81.5	40	80	8.7	5.2	Grade 1
11	40/female	Left	Idiopathic	30.1	60	Stage 2	182°	60	88.7	64	83	8.1	2.8	Grade 1
12	44/female	Right	Corticosteroid	27.5	54	Stage 2	188°	56.2	90	60	86	7.5	3.3	Grade 1

BMI, Body Mass Index; CAN, Combined Necrotic Angle; HHS, Harris Hip Score; N, Patients Number; NAHS, Non-Arthritic Hip Score; ON, Osteonecrosis; Post, Postoperative; Pre, Preoperative; VAS, Visual Analogue Scale.

37.5%) and endogenous hypercortisolism secondary to Cushing's disease in two patients (three hips; 18.75%). Five patients (five hips; 31.25%) had no apparent associated risk factor and were deemed idiopathic osteonecrosis (Table 2).

According to the Association Research Circulation Osseous (ARCO) classification system[13]; seven hips (43.7%) were classified as stage 2 (five hips: stage 2A and two hips: stage 2B) and nine hips (56.3%) were classified as stage 3 (six hips: stage 3B and three hips: stage 3C), preoperatively.

Combined necrotic angle was 198.7° ± 13.2°(range: 180°-220°), on average. Based on the magnitude of resulting combined angle, hips were classified into four categories (grade 1: <200°; grade 2: 200°to 249°; grade 3: 250°to 299°; grade 4: ≥300°).[19] According to this evaluation, seven hips (43.7%) were classified as grade 1 and nine hips (56.3%) as grade 2.

The average follow-up period was 48.4 ± 25.7 months (range: 12-107). All patients had an uneventful postoperative course without any intraoperative or early postoperative complications.

On the final follow-up, mean HHS increased from 53.43 ± 9.0 (range: 36-67) to 83.81 ± 6.1 (range: 72-95) ($P < 0.001$), mean NAHS increased from 51.5 ± 8.2 (range: 36.25-61.25) to 86 ± 3.2 (range: 81.5-90) ($P < 0.001$) and mean VAS decreased from 7.85 ± 0.9 (range: 6.45-9.5) to 3.05 ± 0.9 (range: 1.6-5.2) ($P < 0.001$). Thirteen hips (81.2%) had good or excellent results as determined by the HHS system. According to Kellgren–Lawrence scale, three hips (18.75%) were evaluated as grade 0, 10 hips (62.5%) as grade 1 and three hips (18.75%) as grade 2.

When stratified by ARCO staging system, mean postoperative HHS, NAHS and VAS scores in stage 2 hips were 86.2 ± 4.0 (range: 83-95), 88.1 ± 2.1 (range: 83.7-90) and 2.8 ± 0.8 (range: 1.6-4.1), respectively. All of the seven stage 2 hips had good or excellent results. According to Kellgren–Lawrence scale, three hips (42.9%) were classified as grade 0 and four hips (57.1%) as grade 1. In stage 3 hips, mean postoperative HHS, NAHS and VAS scores were 81.8 ± 6.9 (range: 72-94), 84.3 ± 3.0 (range: 81.5-90) and 3.2 ± 1.0 (range: 2-5.2), respectively. Six of the nine stage 3 hips (66.6%) had good or excellent results and all of them were classified as grade 1 according to Kellgren–Lawrence scale. In the remaining three hips with combined necrotic angles greater than 200°(grade 2), hip motions were slightly restricted. Mean postoperative HHS, NAHS and VAS scores of these patients were 76 ± 3.4 (range: 72-78), 82 ± 0.5 (range: 81.5-82.5) and 3.2 ± 0.9 (range: 2.15-4), respectively (Table 2).

According to the evaluation of combined necrotic angle, all of the seven hips (six ARCO stage 2; one ARCO stage 3) with combined necrotic angles of less than 200°(grade 1) had good or excellent results. Of the remaining nine hips (one ARCO stage 2 and eight ARCO stage 3) with combined necrotic angles greater than 200° (grade 2), six hips (66.6%) had good or excellent results.

There were no complications related to the trapdoor replaced without any fixation material. At the most recent follow-up (48.4 months on average), all hips were survived and none of them required further surgery.

Discussion

The main finding of this study is that the modified trapdoor procedure is a safe and effective surgical technique for the treatment of ARCO stage 2 and stage 3 femoral head osteonecrosis. This technique allows the grafting of the femoral head without hip dislocation. Thus, the potential complications of surgical hip dislocation can be prevented.

The rationale for using non-vascularized bone grafting is to remove necrotic bone and replace it with bone grafts that support subchondral bone and articular cartilage (osteoconduction); furthermore, it may stimulate bone formation (osteoinduction).[2,3,6,7] Prognosis of the disease and success of the treatment are related to stage of the disease and size of the osteonecrotic segment in the femoral head. Bone grafting using the Phemister technique can be effective for stage 1 and 2 osteonecrosis.[2] The clinical success rate of this technique ranged from 36% to 90%.[8,20–24] However, because of reported some unfavorable results, most surgeons have investigated other bone grafting techniques.[6]

Lightbulb technique describes filling the femoral head defect with various bone grafting forms through a cortical window in the femoral neck or head–neck junction. The cortical window is then replaced and secured with bioabsorbable pins.[6] Clinical success of the

lightbulb technique ranged from 68% to 87%.[3,9,25–27] Cheng et al.[12] concluded that this procedure did not damage the articular cartilage; however, it encountered two difficult problems. First, it is difficult to remove the necrotic bone segment completely. Second, it cannot be able to perform perfect bone grafting to fill the femoral head.[12]

Trapdoor procedure is nearly identical to the approach of lightbulb technique; however, rather than removing a cortical window from head–neck junction, the femoral head is dislocated anteriorly through an anterior or anterolateral approach and a window is created through the collapsed articular cartilage.[9] As in the lightbulb technique, the lesion is filled with bone grafts; then, the window is closed and secured with two or three bioabsorbable pins.[5,6] The clinical success of the trapdoor procedure ranged from 62% to 100% (Table 3).[4,5,28–30] This technique was first described in 1983 by Meyers et al.[4] They reported marked improvements in pain and function in 15 out of 21 hips (71%) after a minimum follow-up of 18 months. About a decade later, this method was implemented by Ko et al.[29] in a cohort of teenagers who had femoral head osteonecrosis (n = 14 hips). After a mean follow-up of 53 months (range: 24-108), none of the hips required further procedures at their latest follow-up.

The most well-known article about trapdoor procedure was reported by Mont et al.[5] They reviewed the results of 30 operations performed on 23 patients with stage 3 or 4 osteonecrosis. At a mean follow-up period of 56 months (range: 30-60), 20 of 24 stage 3 hips (83%) had good or excellent results. However, two of six stage 4 hips (33%) had good or excellent results. Eighteen of 21 hips (86%) with a combined necrotic angle of 200° had good or excellent results compared with only four of nine hips (44%) with a combined necrotic angle of more than 200°. Six of the eight hips with fair or poor results were in patients who had received corticosteroids; five of these six hips had lesions with a combined necrotic angle greater than 200° or were in a late-stage (stage 4). They concluded that the trapdoor procedure could be successful in stage 3 hip osteonecrosis in patients with small- to medium-sized lesions.

Cheng et al.[12] described a trapdoor procedure modification without using a surgical hip dislocation. They modified the technique using autogenous tricortical iliac graft without preserving the broken articular cartilage and compared the results to a group of patients operated on by using lightbulb procedure. They suggested that their modification was associated with better clinical and radiographic results than the lightbulb procedure in femoral head osteonecrosis, particularly in those with ARCO stage 3 disease. Their technique shows some similarities with our modification including an anterior approach without using surgical hip dislocation and trapdoor segment created on the anterior part of the femoral head. However, they preferred to stabilize tricortical iliac graft with screws and the resected segment of articular cartilage was no longer covered.

Rosenwasser et al.[9] described the lightbulb technique as the concept of debridement of the necrotic area and bone grafting through a cortical window at the femoral head-neck junction. They concluded that this technique is similar to the trapdoor technique except that it spares the articular cartilage. Therefore, we also prefer to describe our technique as a modification of the original trapdoor procedure. In our technique, the window created for grafting of the femoral head is located proximally to the head–neck junction and on the anterior –inferior articular surface of the femoral head. We did not use any implant to fix the replaced trapdoor. The stability of this segment was provided by tightly closing the joint capsule over it. Additionally, the trapdoor segment is located at the anterior and non-weightbearing surface of the femoral head. On the final follow-up, we did not observe any complications related to the trapdoor segment. All hips were survived and none of them required further surgery.

In conventional trapdoor procedure, hip dislocation is generally suggested to access the osteonecrotic lesion fully. However, avascular necrosis of the femoral head is a substantial pitfall in this procedure.[11] It is essential to pay attention to protect circumflex and capsular arteries during exposure. Furthermore, joint dislocation and reduction should be performed gently to avoid disturbance of vascular flow and potential collapse of the femoral head. Other complications of surgical hip dislocation include femoral neck fracture, nerve injury and thromboembolic disease.[11] Sometimes, it necessitates greater trochanteric osteotomy, which brings additional risk of trochanteric nonunion.[11] Another risk for trapdoor procedure with hip dislocation is heterotopic ossification. According to Swiontkowski et al.,[31] the anterior approach seems to be associated with a greater risk of heterotopic ossification than the posterior approach. Ganz et al.[32] described a femoral head dislocation method that involves an anterior dislocation of the hip from a posterior approach with a trochanteric flip osteotomy. They suggested this type of surgical dislocation might be safer than others from an avascular necrosis standpoint. However, this approach includes some potential risks such as increased operative time, blood loss and complications related with the healing period of the trochanteric osteotomy.[11]

This study has some limitations. First, it was a relatively small sample size to fully assess potentially severe complications of the disease and surgical procedure that we did not observe in this study. Nevertheless, the early results encourage the continued use of this procedure. A larger series with longer follow-up will further help assess positive and negative predictors of outcome. Second, we have no comparison group to determine how our results might compare with different approaches to the femoral head that respect the blood supply to the hip, such as anterior dislocation with a posterior approach proposed by Ganz et al.[32] Despite our early clinical success, we expect some hips to deteriorate and require reconstructive surgery later. Nevertheless, the hip joint's survival for an average of 48.4 months (range: 12-107 months) suggests that the natural progression of the disease has been delayed.

The modified trapdoor procedure makes it possible to grafting of the femoral head without surgical hip dislocation. This technique is suitable for the treatment of ARCO stage 2 and stage 3 hip osteonecrosis.

Table 3. Outcomes of Previously Published Trapdoor Procedures

Meyers et al.[4]	1983	21	Non defined	18 (range: 18-60)	71
Ko et al.[29]	1995	14	All collapsed	53 (range: 24-108)	100
Mont et al.[5]	1998	30	Ficat 3-4	56 (range: 30-60)	83
Seyler et al.[3]	2008	39	Ficat 2-3	36 (range: 24-50)	82
Cheng et al.[12]	2020	67	Arco 2-3	91 (range: 75-115)	92

Ethics Committee Approval: Ethics committee approval was received for this study from the Ethics Committee for Scientific Research of Medeniyet University Göztepe Training and Research Hospital with the approval number of 2020/0562.

Informed Consent: Written informed consent was obtained from pateints who participated in this study.

Author Contributions: Concept - M.G.; Design - B.A., M.G.; Supervision - M.G., B.K., Ö. Y., N.K.Ö.; Materials - B.A., B.K., Ö.Y.; Data Collection and/or Processing - B.A., B.K., Ö.Y.; Analysis and/or Interpretation - B.A., B.K., B.Ö.; Literature Review - B.A., B.K., Ö. Y., N.K.Ö., B.Ö.; Writing - M.G.; Critical Review - M.G., Ö.Y., N.K.Ö., B.Ö.

Conflict of interest: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

References

1. Beaule PE, Amstutz HC. Management of Ficat stage III and IV osteonecrosis of the hip. *J Am Acad Orthop Surg*. 2004;12(2):96-105. 10.5435/00124635-200403000-00005
2. Mont MA, Hungerford DS. Non-traumatic avascular necrosis of the femoral head. *J Bone Joint Surg Am*. 1995;77(3):459-474. 10.2106/00004623-199503000-00018
3. Seyler TM, Marker DR, Ulrich SD, Fatscher T, Mont MA. Nonvascularized bone grafting defers joint arthroplasty in hip osteonecrosis. *Clin Orthop Relat Res*. 2008;466(5):1125-1132. 10.1007/s11999-008-0211-x
4. Meyers MH, Jones RE, Bucholz RW, Wenger DR. Fresh autogenous grafts and osteochondral allografts for the treatment of segmental collapse in osteonecrosis of the hip. *Clin Orthop Relat Res*. 1983;174:107-112.
5. Mont MA, Einhorn TA, Sponseller PD, Hungerford DS. The trapdoor procedure using autogenous cortical and cancellous bone grafts for osteonecrosis of the femoral head. *J Bone Joint Surg Br*. 1998;80(1):56-62. 10.1302/0301-620X.80B1.0800056
6. Pierce TP, Elmallah RK, Jauregui JJ, Poola S, Mont MA, Delanois RE. A current review of non-vascularized bone grafting in osteonecrosis of the femoral head. *Curr Rev Musculoskelet Med*. 2015;8(3):240-245. 10.1007/s12178-015-9282-y
7. Mont M, Marulanda G, Seyler T, Plate J, Delanois R. Core decompression and nonvascularized bone grafting for the treatment of early stage osteonecrosis of the femoral head. *Instr Course Lect*. 2007;56:213-220 .
8. Bonfiglio M, Yoke EM. Aseptic necrosis of the femoral head and non-union of the femoral neck: Effect of treatment by drilling and bone-grafting (Phemister technique). *J Bone Joint Surg Am*. 1968;50(1):48-66. 10.2106/00004623-196850010-00003
9. Rosenwasser MP, Garino JP, Kiernan HA, Michelsen CB. Long term followup of thorough debridement and cancellous bone grafting of the femoral head for avascular necrosis. *Clin Orthop Relat Res*. 1994;306:17-27.
10. Yamamoto M, Itoman M, Sagamoto N, Morita M. Strut bone graft for aseptic necrosis of the femoral head: Theory and surgical technique. *Orthop Surg*. 1983;34:902-908.
11. Xu H, Niu X, Li Y, Binitie OT, Letson GD, Cheong D. What are the results using the modified trapdoor procedure to treat chondroblastoma of the femoral head? *Clin Orthop Relat Res*. 2014;472(11):3462-3467. 10.1007/s11999-014-3771-y
12. Cheng QI, Zhao FC, Xu SZ, Zheng L, Zheng X. Modified trapdoor procedures using autogenous tricortical iliac graft without preserving the broken cartilage for treatment of osteonecrosis of the femoral head: A prospective cohort study with historical controls. *J Orthop Surg Res*. 2020;15(1):183. 10.1186/s13018-020-01691-w
13. Gardeniers J. A new international classification of osteonecrosis of the ARCO committee on terminology and classification. *ARCO Newsl 4*. 1992;4(4):41-46.
14. Koo KH, Kim R. Quantifying the extent of osteonecrosis of the femoral head. A new method using MRI. *J Bone Joint Surg Br*. 1995;77(6):875-880. 10.1302/0301-620X.77B6.7593098
15. Harris W. Traumatic arthritis of the hip after dislocation and acetabular fractures: Treatment by mold arthroplasty. *J Bone Joint Surg Am*. 1969;51(4):737-755. 10.2106/00004623-196951040-00012
16. Sim Y, Horner NS, De Sa D, Simunovic N, Karlsson J, Ayeni OR. Reporting of non-hip score outcomes following femoroacetabular impingement surgery: A systematic review. *J Hip Preserv Surg*. 2015;2(3):224-241. 10.1093/jhps/hnv048
17. Huskisson EC. Measurement of pain. *J Rheumatol*. 1982;9(5):768-769.
18. Lawrence RC, Helmick CG, Arnett FC, et al. Estimates of the prevalence of arthritis and selected musculoskeletal disorders in the United States. *Arthritis Rheum*. 1998;41(5):778-799. 10.1002/1529-0131(199805)41:5<778::AID-ART4>3.0.CO;2-V
19. Ha Y-C, Jung WH, Kim J-R, Seong NH, Kim S-Y, Koo K-H. Prediction of collapse in femoral head osteonecrosis: A modified Kerboul method with use of magnetic resonance images. *J Bone Joint Surg Am*. 2006;88(suppl-3):35-40. 10.2106/JBJS.F.00535
20. Smith K, Bonfiglio M, Montgomery W. Non-traumatic necrosis of the femoral head treated with tibial bone-grafting. A follow-up note. *J Bone Joint Surg Am*. 1980;62(5):845-847. 10.2106/00004623-198062050-00028
21. Buckley PD, Gearen P, Petty R. Structural bone-grafting for early atraumatic avascular necrosis of the femoral head. *J Bone Joint Surg Am*. 1991;73(9):1357-1364. 10.2106/00004623-199173090-00011
22. Keizer SB, Kock NB, Dijkstra PD, Taminiau AH, Nelissen RG. Treatment of avascular necrosis of the hip by a non-vascularised cortical graft. *J Bone Joint Surg Br*. 2006;88(4):460-466. 10.1302/0301-620X.88B4.16950
23. Lieberman JR, Conduah A, Urist MR. Treatment of osteonecrosis of the femoral head with core decompression and human bone morphogenetic protein. *Clin Orthop Relat Res*. 2004;429:139-145. 10.1097/01.blo.0000150312.53937.6f
24. Steinberg ME, Larcom PG, Strafford B, et al. Core decompression with bone grafting for osteonecrosis of the femoral head. *Clin Orthop Relat Res*. 2001;386:71-78. 10.1097/00003086-200105000-00009
25. Mont MA, Etienne G, Ragland PS. Outcome of nonvascularized bone grafting for osteonecrosis of the femoral head. *Clin Orthop Relat Res*. 2003;417:84-92.10.1097/01.blo.0000096826.67494.38
26. Saito S, Ohzono K, Ono K. Joint-preserving operations for idiopathic avascular necrosis of the femoral head. Results of core decompression, grafting and osteotomy. *J Bone Joint Surg Br*. 1988;70(1):78-84. 10.1302/0301-620X.70B1.3276703
27. Yildiz C, Erdem Y, Koca K. Lightbulb technique for the treatment of osteonecrosis of the femoral head. *Hip Int*. 2018;28(3):272-277. 10.5301/hipint.5000576
28. Meyers MH, Convery FR. Grafting procedures in osteonecrosis of the hip. *Semin Arthroplasty*. 1991;2:189-197.
29. Ko J-Y, Meyers MH, Wenger DR. "Trapdoor" procedure for osteonecrosis with segmental collapse of the femoral head in teenagers. *J Pediatr Orthop*. 1995;15(1):7-15. 10.1097/01241398-199501000-00003
30. Mont MA, Jones LC, Einhorn TA, Hungerford DS, Reddi AH. Osteonecrosis of the Femoral Head: Potential Treatment With Growth and Differentiation Factors. *Clin Orthop Relat Res*. 1998; 355 (Suppl):314-335. 10.1097/00003086-199810001-00032
31. Swiontkowski M, Thorpe M, Seiler J, Hansen S. Operative management of displaced femoral head fractures: Case-matched comparison of anterior versus posterior approaches for Pipkin I and Pipkin II fractures. *J Orthop Trauma*. 1992;6(4):437-442. 10.1097/00005131-199212000-00008
32. Ganz R, Gill T, Gautier E, Ganz K, Krügel N, Berlemann U. Surgical dislocation of the adult hip: A technique with full access to the femoral head and acetabulum without the risk of avascular necrosis. *J Bone Joint Surg Br*. 2001;83(8):1119-1124. 10.1302/0301-620X.83B8.0831119