Journal of Orthopaedic Translation (2019) 19, 126–132

Available online at www.sciencedirect.com

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journal homepage: http://ees.elsevier.com/jot

ORIGINAL ARTICLE

Treatment of femoral neck nonunion with a new fixation construct through the Watson-Jones approach

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Received 5 November 2018; received in revised form 24 February 2019; accepted 4 April 2019
Available online 28 April 2019

KEYWORDS
Bone nonunion;
Delayed union;
Femoral neck fracture;
Watson-Jones approach

Abstract *Objective:* The aim of the study is to explore the clinical effect of a dynamic condylar screw (DCS) system, medial anatomical buttress plate (MABP), and autogenous iliac bone graft through the Watson-Jones approach in the treatment of femoral neck nonunion.
Methods: This prospective study included 15 patients (12 men and 3 women) with nonunion of femoral neck fracture, who were treated with the DCS and MABP with autogenous iliac bone graft through the Watson-Jones approach. The patients were followed up for an average of 16 months (range, 12–24 months).
Results: All patients achieved bone healing with an average fracture healing time of 3.4 months (2.8–4.6 months). The Harris score significantly increased from 30 ± 3.9 before the operation to 87.6 ± 7.9 at the last follow-up, and the visual analogue scale significantly decreased from 4 ± 1.3 before the operation to 1 ± 1.7 at the last follow-up. The average limb shortening was reduced from 1.8 cm (range, 0–3.1 cm) before the revision operation to 0.5 cm (range, 0.1–1.3 cm) after the last follow-up. The neck-shaft angle of the injured side was restored from an average of 118° (range, 108–139°) before the revision operation to an average of 132° (range, 127–144°) at the last follow-up. No collapse of the femoral head, wound infections, screw backout, screw or plate breakages, or nerve injury was found.
Conclusion: TheDCS and MABP with autogenous iliac bone graft through the Watson-Jones approach is an effective option for the treatment of femoral neck nonunion or delayed healing.
The translational potential of the article: This article shows that the application of DCS and MABP provides a rigid fixation at the fracture site to promote bone graft integration and bone union. This new kind of technique could be one option of Hip conservation procedures, just special for young patients with femoral neck nonunion.

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https://doi.org/10.1016/j.jot.2019.04.004

Introduction

Type III femoral neck fractures frequently occur as a result of high-energy trauma, characterized by a vertical fracture of the femoral neck. Owing to the high shear load at the fracture site, Type III femoral neck fractures are commonly associated with a high nonunion rate of 10—30% in young adults after the primary operation [1—3]. Hip conservation or joint replacement is performed as a revision operation for the treatment of femoral neck nonunion. For young adult patients with femoral neck nonunion, hip conservation is selected as the first choice for revision operation because joint replacement is associated with poor long-term outcomes [1].

Hip conservation procedures mainly include valgus osteotomy and grafting procedures. However, both procedures are associated with unfavourable outcomes for the treatment of fracture neck nonunion. For example, valgus osteotomy can promote fracture healing through the realignment of the fracture plane to a more horizontal position, thus converting shear force into compressive force. However, the alteration of biomechanical conduction can result in several complications such as discrepancy of limbs and reduction of hip joint activity [4—7]. Various bone grafting techniques are used with cephalomedullary implants as supplemental fixation to augment the stability of the femoral neck, including one cancellous screw, two to three cancellous screws, or an angle blade plate to offload shearing force over the bone strut [8—13]. These grafting procedures, however, are associated with complications due to insufficient stability at the fracture site, such as fibular graft fracture, fibular graft slippage, and instability of the implanted femoral neck, and the postoperative hip spica is often required [8,9,12].

Dynamic condylar screw (DCS) can provide strong stability at the fracture site for the treatment of Type III femoral neck fractures [14,15], and the proximal femoral medial plate can effectively resist shear force [16,17]. The combination of the DCS and proximal femoral medial plate provides more stability at the fractures sites for femoral neck nonunion. However, their combination requires two surgical approaches such as the lateral approach and the Smith-Peterson approach, thus resulting in excessive traumatic exposure. In this study, we adopted the Watson-Jones approach to treat femoral neck nonunion, using the DCS in combination with the medial anatomical buttress plate (MABP). The MABP has a special anatomical design in which its proximal part directly supports the femoral head to resist shear force, and its distal part is fixed to the anterior part of the femur. This method provided a rigid fixation at the fracture site to promote bone graft integration and bone union.

Methods

Patient selection

This study was approved by the ethics committee of the local hospital, and all patients were recruited from the Trauma Center of the General Hospital of People's Liberation Army. This study included 15 patients (12 men and 3 women) with femoral neck nonunion, who were treated with the DCS system and MABP with the autogenous iliac bone graft through the Watson-Jones approach from December 2014 to March 2016. The patients were selected based on the following criteria: (1) the fracture did not heal at 9 months postoperatively or the fracture had no signs of healing at 4—6 months postoperatively, as indicated by bone absorption in the fracture ends and progressive displacement of the hip varus and (2) bleeding of the femoral head was observed after drilling with K-wire intraoperatively. The patients were excluded if Magnetic resonance imaging (MRI) examination showed signs of femoral head ischaemia or signs of infection as indicated by the normal levels of erythrocyte sedimentation rate, c-reactive protein test (C-Pro), white blood cells, and interleukin-6 in the blood.

Surgical procedures

Under epidural anaesthesia or general anaesthesia, the patient was placed in the supine position on the operative bed. The affected limb was tractioned and was rotated to make the patella perpendicular to the ground. The healthy side of the limb was maintained on the position of slight flexion and abduction.

The hip joint was exposed through the Watson-Jones approach [18]. The proximal part of the incision was about 6 cm, extending proximally from the greater trochanter and arcing to the iliac crest nodules. The distal part of the incision was about 7 cm, extending distally to the lesser trochanter along the axis of the femur. The greater trochanter and the gluteus medius muscle were exposed through the sharp incision of the fascia along the posterior landmark of the tensor fascia lata. Hoffman retractors were placed on the anterior margin of the acetabulum and the medius gluteus muscle. The hip capsule was exposed proximally by anteriorly pulling the tensor fascia lata and posteriorly pulling the medius gluteus muscle with the retractors and distally by pushing away the lateral femoral muscle underneath the periosteum. The fracture site was exposed through the L-shaped incision of the hip joint capsule, and the primary internal fixation was removed. A cortice window at the fracture site was made, originating from the base of the femoral neck, through the fracture site, to the femoral head. The fibroconnective tissues at the fracture were removed with a rongeur, and the sclerotic bone in the fracture ends was ground with a grinding drill. The femoral neck was realigned with traction of the affected limb and fixed with the DCS (Tianjin Zhengtian Medical Instrument Co., Ltd, China) with the monitoring using fluoroscopy. The bone paste, which consisted of grounded cortical and cancellous bone that was harvested from the outer surface of the posterior iliac wing using an acetabular reamer, was impacted into the bone window. The solid bone grafts from the cortice of the iliac crest were pushed inside the bone window. The MABP (Tianjin Zhengtian Medical Instrument Co, Ltd) was used to fix the femoral neck, and the proximal part of the plate was placed below the femoral neck fracture site to make a direct support of the femoral head.

Postoperative management

Range of motion of joint and isometric contraction muscle exercises was encouraged immediately after surgery. The patients initiated nonweight-bearing joint activities immediately after the operation and started partial weight-bearing activities (with 15 kg weight) 6 weeks after the revision surgery. The patients performed full weight-bearing activities when radiological examinations confirmed the healing of the fracture. The patients were followed up every 4 weeks with X-ray and clinical evaluations; and a three-dimensional computed tomography (CT) examination with a metal suppression protocol was performed at 3 months after the operation. For all patients, fracture healing was confirmed by CT at 3 months after operation. After the fracture healed, a follow-up was done every 6 months. Radiological assessment of the fracture healing, necrosis of the femoral head, and complications associated with internal fixation were recorded. The neck-shaft angle of the femoral neck was measured on a standard orthotopic image before revision operation and at the last follow-up. The limb length discrepancy was measured using computer tomography scanograms, as previously described [19], by determining the difference in the distance between the lesser trochanter and the horizontal line drawn through the pelvic teardrops between the bilateral femurs.

The evidence of fracture healing included complete weight-bearing without hip pain by clinical evaluation, trabeculae bridging through fractured ends on the anteroposterior X-ray film, and three-dimensional trabecular bone trabeculae through fracture ends on CT images. The Harris score [20] and visual analogue scale score [21] were used for clinical evaluations.

Statistical analysis

Statistical analyses were performed using SPSS 20.0 statistical software, IBM, Chicago, IL, USA. Data are presented as mean and standard deviation. A paired t test was used to compare differences between groups. A P value of <0.05 was considered statistically significant.

Results

A total of 15 patients were included in this study. Table 1 lists the clinical characteristics of the 15 patients preoperatively. The average age of these patients was 39.1 years (range, 20–63 years). The fracture occurred on the left in nine cases and on the right in six cases. The original causes for the injuries were accident injury in six cases, falling from the height in eight cases, and running down in one case. In the primary operation, three cannulated

Table 1 Patients' characteristics preoperatively.

No.	Sex	Age	Injured side	Previous internal fixation	Time since injury (months)	AVN	Shortening (cm)	Pauwel's angle	NSA (injured)	NSA (affected)	Harris score	Pain VAS
1	M	29	R	Screw (2)[a]	11	0	0	77	139	140	36	40
2	M	48	L	LCP	12	1	3.2	76	108	142	28	40
3	M	20	R	Screw (4)	9	0	1.5	64	119	128	29	40
4	M	35	L	Screw (3)	6	2	3.1	69	114	133	34	80
5	F	43	R	LCP	24	0	1.5	32	120	138	32	40
6	M	29	L	LCP	6	0	2.3	68	108	144	35	40
7	F	36	R	LCP	10	0	1.6	75	119	130	25	30
8	F	44	L	Screw (3)	8	0	2	46	118	136	25	30
9	M	35	L	Screw (3)	5	0	2	66	108	144	27	40
11	M	28	L	Screw (3)	9	0	1.4	46	126	134	28	30
10	M	63	R	DHS	10	0	1	67	132	139	29	30
12	M	41	R	Screw (3)	6	0	2	53	110	134	25	40
13	M	53	L	Screw (3)	5	0	1.8	79	114	127	36	30
14	M	45	L	Screw (3)	9	0	2	65	120	136	32	20
15	M	38	L	Screw (3)	9	0	1.6	63	118	136	29	40

AVN = avascular necrosis of femoral head and associated Ficat classification; DHS = dynamic hip screw; LCP = locking compression plate;NSA = neck-shaft angle; pain VAS = pain visual analogue scale.

[a] Screw means "cannulated screw", (2) means the number of the screws.

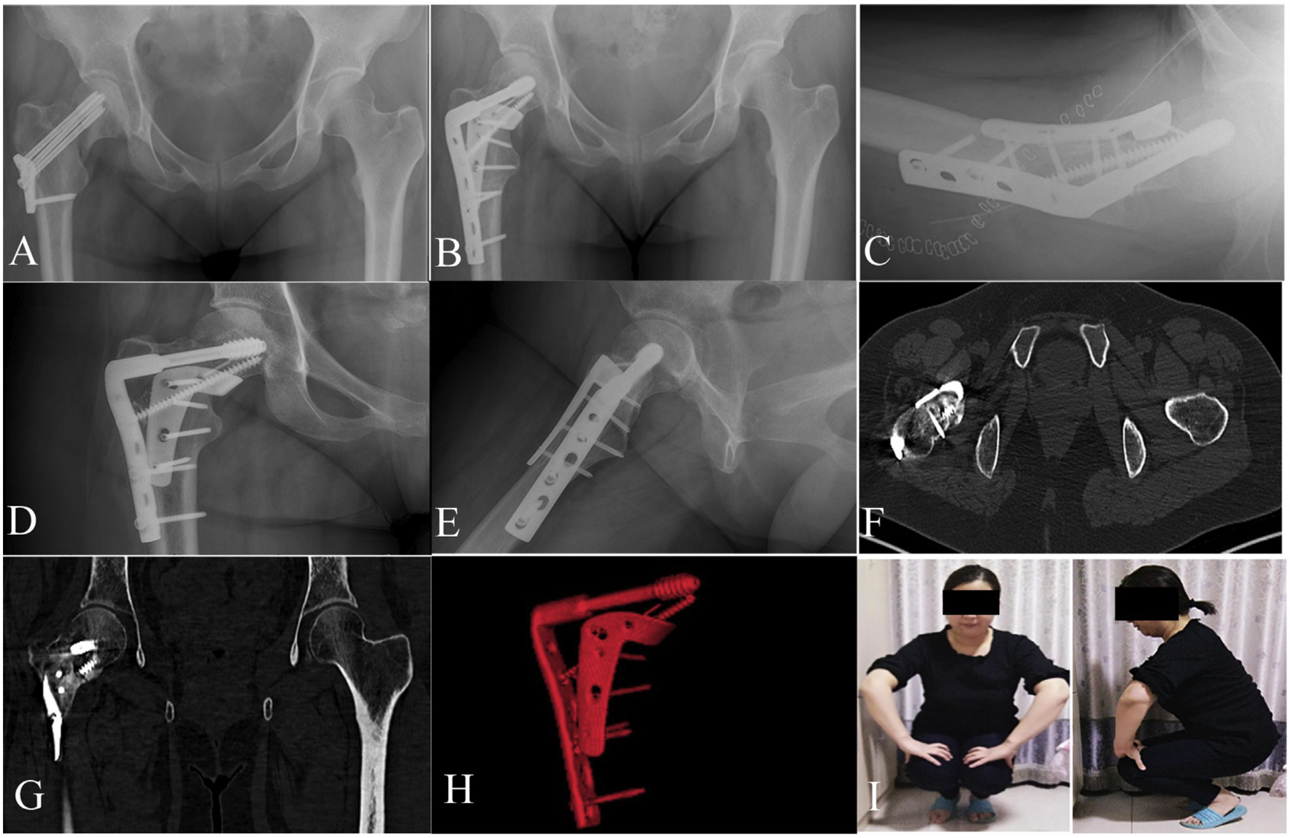

Figure 1 A 36-year-old woman with femoral neck fracture of a Pauwel's angle of 75° had unhealed fracture 10 months after open reduction and internal fixation using the locking plate. The X-ray films (A) before and (B, C) after the patient was treated with the dynamic condylar screw system with medial anatomical buttress plate and autogenous iliac bone graft through Watson-Jones approach; (A, B) anteroposterior view (AP); (C) lateral view showing the proximal part of the medial anatomical buttress plate being placed inferior to the femoral neck fracture site and directly resists the shear force at the fracture site. The (D) AP view and (E) lateral view of the X-ray film at 3 months postoperatively confirmed bone healing. The (F) sagittal view and (G) coronal view of three-dimensional (3D) computed tomography (CT) examinations show that bone trabeculae bridged through the fracture site of the femoral neck. H. 3D CT reconstruction with a metal suppression protocol shows the relationship between the DCS and MABP. (I) At 6 months after the operation, the patient had a functional recovery and was free to walk, run, and squat with a Harris score of 87. DCS, dynamic condylar screw; MABP, medial anatomical buttress plate.

Table 2 Clinical and functional outcomes.

No.	Healing time (months)	Shortening (cm)	NSA (injured)	Harris score	Pain VAS
1	3.5	0	139	97	0
2	3.2	2	136	89	20
3	3	0.5	128	100	0
4	3	2	128	65	60
5	3.5	0.5	135	85	20
6	4	0	124	91	20
7	3.4	0	132	87	0
8	3	0	133	85	20
9	3.3	1	139	83	0
10	4	0	129	94	0
11	3.5	0	141	87	0
12	4.6	0	131	85	0
13	2.8	0	123	91	0
14	3.6	0	136	85	0
15	3.2	0	132	91	0

NSA = neck-shaft angle; pain VAS = pain visual analogue scale.

screws were used in 10 cases, dynamic hip screw (DHS) + single cannulated screw was used in one case, and locking plate fixation was used in four cases. The average shortening of the lower extremity was 1.8 cm (range, 0–3.1 cm). All patients had different degrees of pain when walking with or without assistance or when bearing a load. The average time interval between the revision operation and the primary operation was 9.3 months (range, 5–24 months).

All 15 patients were followed up for an average of 16 months (range, 12–24 months). All patients achieved bone healing after an average time of 3.4 months (range, 2.8–4.6 months) (Fig. 1).

Table 2 lists the functional outcomes of the 15 patients at the last follow-up. The Harris score was significantly increased from 30 ± 3.9 before revision operation to 87.6 ± 7.9 at the last follow-up, and the visual analogue scale score was significantly decreased from 4 ± 1.3 before revision operation to 1 ± 1.7 at the last follow-up, suggesting that the patient's quality of life was improved after revision operation.

The average limb shortening was reduced from 1.8 cm (range, 0—3.1 cm) before revision operation to 0.5 cm (range, 0.1—1.3 cm) after the last follow-up. The average Pauwel's angle of the femoral neck fracture remained unchanged [63° (range, 32—79°) before revision operation vs 62° (range, 30—76°) at the last follow-up]. The neck-shaft angle of the injured side was restored from an average of 118° (range, 108—139°) before revision operation to an average of 132° (range, 127—144°) at the last follow-up. There was no significant difference in the neck-shaft angle between the injured side and the healthy side at the last follow-up.

No complications such as collapse of the femoral head, wound infections, screw backout or screw or plate breakage, and nerve injury were observed.

Discussion

Achieving mechanical stability at fracture sites is important for successfully treating femoral neck nonunion. However, DHS and DHS plus antirotation screw and multiple hollow screws, which provide sliding compression at the fracture site, might not provide enough stability for femoral neck nonunion [22]. This case series study used the DCS and MABP with the autogenous bone graft to treat femoral neck fracture nonunion. We found that this method effectively healed femoral neck nonunion and achieved satisfactory recovery of hip joint function after surgery. Although the DCS and MABP are not intended for the use of treating femoral neck fractures, the DCS combined with the MABP can create rigid biomechanical stability for the autogenous bone graft, thus promoting bone union and solid graft integration. the DCS combined with the MABP can improve biomechanical stability in three ways (Fig. 2): (1) the MABP resists shear force and promotes fracture healing by directly supporting the femoral neck fracture site to allow the medial cortex of the fracture ends to closely contact each other, thus enabling the recovery of the compressive trabecular bone; (2) the 90° DCS, which is placed at the lower or caudal half of the femoral head and in parallel to the axis of the neck, holds the femoral head through the proximal lateral cortex and promotes the recovery of tensile trabecular bone of the femoral neck; and (3) the head screw and the calcar screw are fixed to the femoral head through the DCS plate, achieving plane stability of the proximal femur to control the rotation of the proximal end at the fracture site.

The key to successfully repairing femoral neck nonunion is to create biomechanical stability at the fracture site by eliminating shear force that causes varus displacement and compressive force that causes femoral neck shortening. In this study, valgus osteotomy was not performed because valgus osteotomy alters the biomechanical conduction of the joint through realigning the fracture plane into a more horizontal position, thus resulting in conversion of shear force into compressive force. The change in the biomechanical conduction of the joint can result in irreversible consequences such as discrepancy of limbs and reduction of hip joint activity [4—7]. Although grafting procedures are

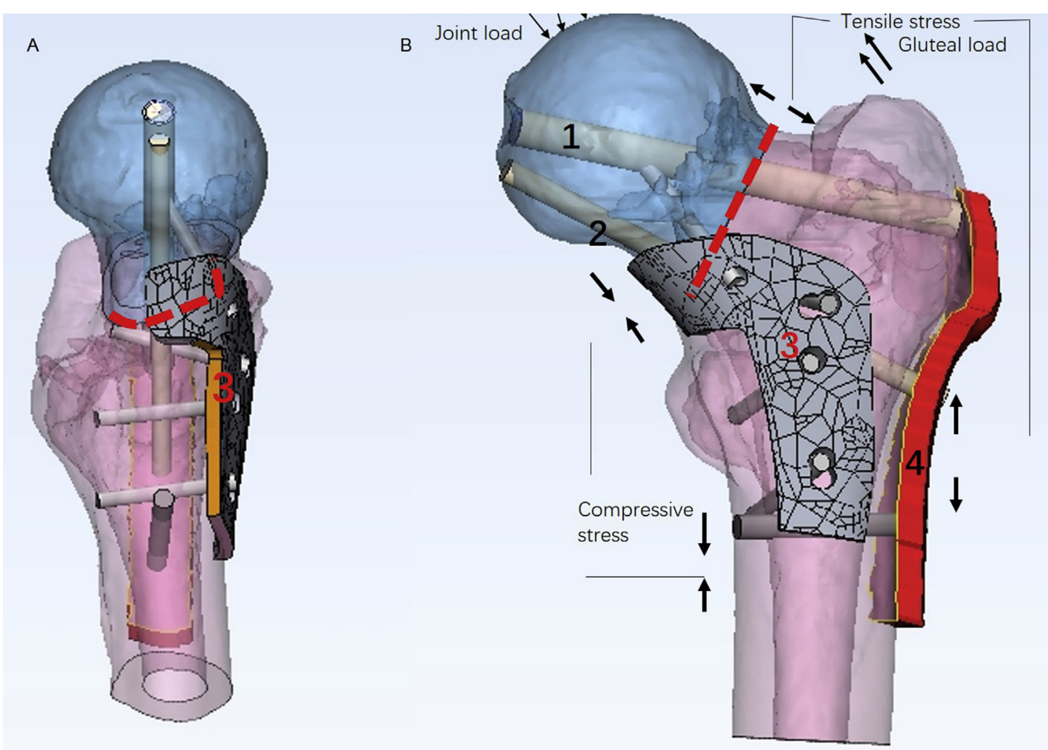

Figure 2 Schematic diagram showing the operative technique with the DCS and MABP. (A) Anteroposterior view. (B) Medial view: (1) head screw; (2) calcar screw; (3) MABP; and (4) DCS plate. Red dotted lines illustrate the femoral neck fracture site.

used to eliminate the forces without changes in the biomechanical conduction of the joint, postoperative hip spica is required because grafting procedures are associated with complications due to insufficient stability of the implanted femoral neck, such as bone graft fracture and bone graft slippage [8]. To boost the stability of the femoral neck after bone graft transplantation, 2–3 parallel cancellous bone screws are placed [9,12]. However, after removing the primary fixation of the femoral neck, complications such as osteopenia of the femoral head, defect of the femoral head, and absorption of the bone at the fracture site that causes the shortening of the femoral neck can occur. Thus, the implantation of cancellous bone screws does not produce sufficient holding force of the femoral head. To further enhance the biomechanical stability at the fracture site, the angle blade plate surgery, with or without cancellous bone screws, is believed to provide antirotation and shear force resistance [11]. However, the consistency between the angular plate (130) and the femoral neck-shaft angle enables the femoral end to be compressed, which further causes shortened femoral neck and limb discrepancy [11].

Although the DCS provides strong stability at the fracture site [14,15], it is infrequently used in the treatment of Pauwel's Type III femoral neck fractures because it promotes bone healing [23]. A Sawbone biomechanical study has showed that the DCS can stabilize Pauwel's Type III femoral neck fractures [15]. Although compared with the proximal femoral locking plate, the DCS offers less stability comfort for femoral neck Pauwel's Type III fractures; the proximal femoral locking plate fails to allow fracture compression at the fracture site, which may negatively affect femoral neck healing [14]. The stability achieved by the DCS alone is dependent on the hold of the condylar screw in the femoral head, which is inadequate to resist the shear force at a femoral neck nonunion fracture site because the femoral head has already been weakened by previous fixation. The proximal femoral medial plate, which can effectively resist shear force, corrects this disadvantage of the DCS. Because the proximal femoral medial plate effectively resists shear force but not compressive force, the proximal femoral medial plate with the DCS or 7.3-mm hollow screw proves to be partially biomechanically plausible and clinically successful to treat Pauwel's Type III femoral neck fractures [16,17]. The combination of the DCS and proximal femoral medial plate can resist shear force and compressive force at the fracture site and thus promotes the healing of femoral neck nonunion. However, this method is not optimal because two incisions are required to complete the operation: the Smith-Peterson approach for the proximal medial plate and the lateral approach to remove the primary fixation or insert additional fixation. In this study, we used the DCS in combination with the MABP via the Watson-Jones approach, in which only one incision was created.

The autologous iliac bone strut and bone paste are regarded as an effective method to promote osteogenesis [24]. In this study, we found that the newly formed bone bridged the fracture ends quickly, resulting in a shorter union time of about 3.4 months compared with previous studies in the literature [4,7,10,12,13]. This is because the DCS and MABP provide a rigid stability that allows osteogenesis of the autologous iliac bone strut and bone paste. Because the neck-shaft angle was recovered after revision surgery, no further shortening of the femoral neck occurred, and the patients' hip joints were functional. The DCS and MABP were placed via a single surgical approach, thus protecting blood supply at the surroundings of the femoral head and decreasing the potential risk of deterioration of femoral head necrosis. No signs of aggravation of femoral head necrosis and collapse of the femoral head occurred in this study, suggesting that the technique used in this study with the autologous iliac bone strut and bone paste promoted the revascularization of the femoral head and prevented the development of disease.

Although the results of this study are encouraging, there are some limitations in this study. First, this is a consecutive case series study without a control group. A case–control study is required to confirm the beneficial effect of this method for the treatment of femoral neck fracture nonunion. Second, this study included 15 patients with femoral neck fracture nonunion. The sample size was relatively small. Third, this study was performed by the same surgeon in a single centre. Further multicentre studies with a larger sample size are required to confirm the clinical efficacy of our method.

In conclusion, this retrospective study showed that the DCS and MABP augmented with the autologous iliac bone strut and bone paste may be a good option for the treatment of femoral neck fracture nonunion.

Conflict of interest

The authors have no conflicts of interest to disclose in relation to this article.

Source of funding

None declared.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jot.2019.04.004.

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