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ORIGINAL STUDY

An evaluation of treating non-union of femoral neck fractures with valgus angulation osteotomy using sliding hip screws

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This study presents the outcomes of patients treated with non-union of femoral neck fractures healed with valgus osteotomy, fixed with a Dynamic Hip Screw (DHS). The study retrospectively evaluated 16 patients who, between 2007 and 2014, developed pseudarthrosis following treatment for a femoral neck fracture and who were treated with DHS-osteosynthesis, after a valgus subtrochanteric osteotomy. Postoperative clinical evaluation of the patients was done? using the Harris Hip Scoring (HHS) system.

Union of both the fracture and the osteotomy site was achieved in 17.2 weeks (range: 14-24 weeks) in all patients. The average Pauwels angle decreased from 72o (range 62–80) preoperatively to 26o (range 20–50) postoperatively. All fractures were Pauwels type III preoperatively and 4 type II and 12 type I postoperatively. The average HHS increased from 26 (range 18–34) preoperatively to 85 (range 68–94) postoperatively. Of the patients who were followed up for a mean duration of 3.1 years (range: 1-5 years), four had 1-cm shortening. No patient developed postoperative AVN of the femoral head.

For patients with non-union after femoral neck fracture, DHS-osteosynthesis after valgus osteotomy is a method with a shorter learning curve, which can be successfully performed.

Keywords : Collum femoris fracture ; non-union ; valgus osteotomy ; osteosynthesis with DHS.

Level of Evidence: Therapeutic Level IV

INTRODUCTION

Femoral neck fractures can occur in any age group; however, these are challenging fractures due to the high post-treatment incidence of non-union and avascular necrosis, particularly in young patients. Three to five percent of all femoral neck fractures occur in young patients and they are often a result of high-energy trauma. Despite the new implants developed, the incidence of non-union in these cases varies between 10% and 59%, depending on the fracture type, the starting time of treatment and the surgical technique. The incidence of avascular necrosis is between 10% and 55% *(6,8,18,19,21,22)*.

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Other methods, such as arthroplasty, are commonly used for the treatment of elderly patients due to these high complication rates, whereas internal fixation methods are preferred for young patients. The purpose of the treatment in young patients is to ensure the patient is able to use his/her own femur neck. Several surgical methods have been described for patients previously treated for this fracture but who have unfortunately developed a non-union *(1,2,4,7,22,23)*.

The most commonly used method is a Pauwels' intertrochanteric osteotomy, fixed with a blade plate *(18,21,22,28)*. Pauwels has suggested that in young patients, non-union and fixation loss in high-energy fractures are caused by mechanical factors. He has argued that biomechanical factors are more important than biological factors during healing of a femoral neck fracture *(28)*. Indeed femoral neck non-union was often a result of abnormal shear forces acting across the fracture site; after a valgisation osteotomy, these unfavorable shear forces one convented into favorable compression forces thus stimulating fracture healing. Excellent results have been reported in a number of studies *(18,13,16,21,28)*. Despite its success, technical difficulties and need of experience with angle plates, which are not regularly used by many orthopedists, have prevented this method from becoming widespread. To overcome these challenges, in recent years, fixation with dynamic hip screws (DHS) instead of angle plates has been used. There is however, only limited literature reporting the outcomes of patients undergoing osteosynthesis with DHS after osteotomy *(13,18,21)*.

The present study evaluated the outcomes of DHS-osteosynthesis after modified Pauwels' osteotomy in young patients who had had internal fixation of a femoral neck fracture and who had subsequently developed a non-union.

MATERIALS AND METHODS

This study retrospectively evaluates 16 patients healed in our department between 2007 and 2014 with an intertrochanteric valgus osteotomy fixed with a DHS for pseudarthrosis of a femoral neck fractures. All the patients were in good health before the fracture and walked unaided. Patients with systemic or metabolic diseases, pathological fractures, avascular necrosis (AVN) of the femoral head (on plain radiography or magnetic resonance imaging (MRI)) and a follow-up duration of less than one year, were excluded. Additionally, ten patients who had osteosynthesis with wedge plates were excluded for the same reason. The patients' files included in the study were reviewed in order to determine the type of injury, type of fracture preoperative and postoperative findings, operation notes, accompanying injuries, presence of infection at follow-up, immobilization time and the time to full weight bearing.

The fractures occurred as a result of a motor vehicle accident in seven patients, a simple fall in six and a falling from a height in another three. All patients were initially healed with cannulated screws. At the time non-union was diagnosed, they complained of pain, limitation of hip motion and immobility to walk without external aids. Non-union was defined as absence of … healing on anteroposterior and lateral radiographs at six months following surgery. Before the osteotomy, a bone scan was carried out in all patients to rule out AVN of the femoral head. C-reactive protein (CRP) and erythrocyte sedimentation rates (ESR) were obtained in all cases, to rule out infection. The period between revision surgery and injury was 7,9 (3 to15) months. Prior to osteotomy, the average neck-shaft angle was 102o (80o – 120o).

A successful outcome of the surgical technique begins with preoperative planning. Preoperative and postoperative sketches are essential. The hip of a patient laid on a radiolucent table was heightened to 15-20 degrees. The skin incision is directly lateral and straight. The tendon of origin of the vastus lateralis is identified and incised 1 cm from the bone to allow repair. The muscle is elevated from the bone and reflected anteriorly. All fixation devices are removed. Initially, a guide pin is placed toward the center of the head at the pre-templated pin insertion angle. To allow for ease of reduction of the osteotomy, the lateral insertion point of the pin should be at the superior edge of the osteotomy. After the pin …, adequate, it is measured for screw length, in determined and the neck and head are

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reamed to appropriate length of the hip screw. The hip screw is then inserted into the femoral neck and head. Fibrous tissue at the nonunion site prevents rotation of the femoral head during insertion of the hip screw. However if gross motion at the non-union site exists, an interfragmentary screw may be placed proximally in the neck to act as a derotation screw (Fig. 1,2).

The level of the osteotomy is planned at or slightly superior to the lesser trochanter and is identified with fluoroscopy. The osteotomy is initiated with a horizontal cut at the intertrochanteric region. The second cut is begun inferiorly toward the apex of the osteotomy to produce the preoperatively planned osteotomy. Both cuts are initiated with a saw and completed with an osteotome. During the osteotomy, the cut is made in such a way that the osteotome does not exceed the bone by performing a corticotomy. Considering the correction of rotation, the wedge is removed with osteotomy from the proximal. Additionally, lateral displacement is formed in order to correct the displacement to the lateral at the mechanic axle due to valgisation (Fig. 3,4).

Fig. 1. — 22 years old male patient treated with canulated screws x ray (6 months after the first operation)

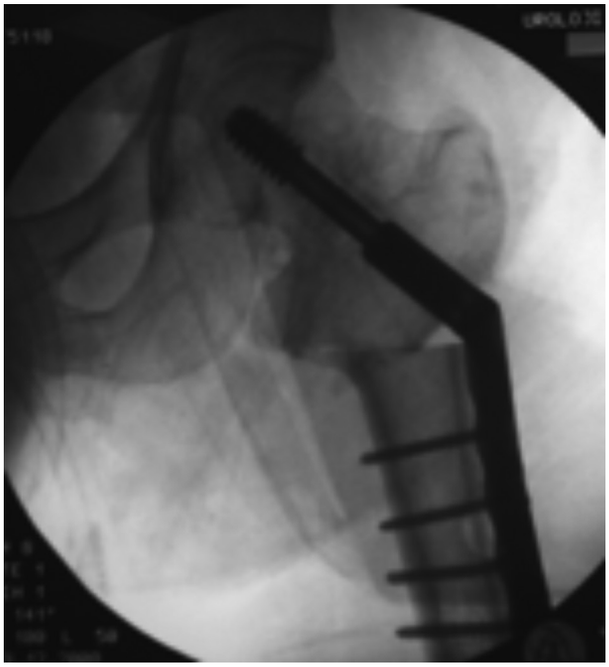

Fig. 2. — Introperative flouroscopic image

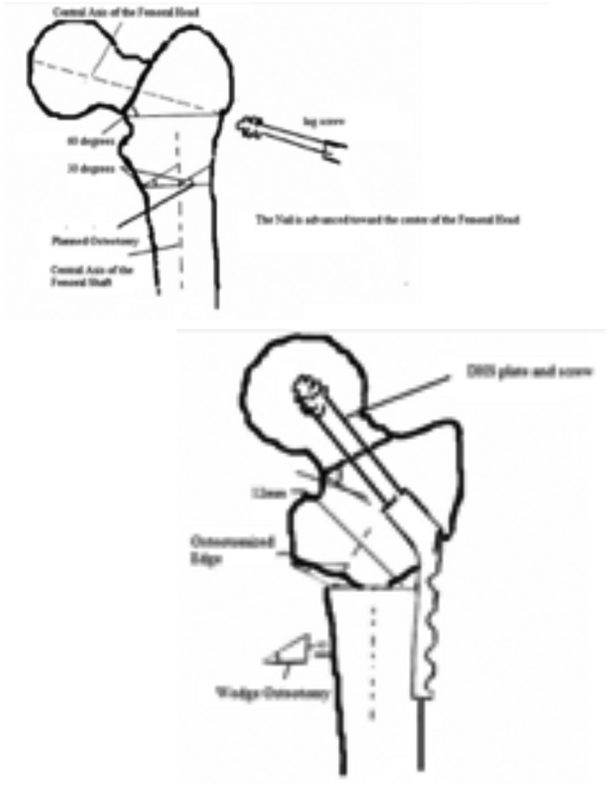

Fig. 3-4. — Diagrams showing preoperatif planning of osteotomy and change in fracture inclination at the completion of the osteotomy and fixation with DHS

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The plate is inserted over the hip screw. The femoral neck and head are brought into valgus and the side plate is then fixed to the femoral shaft. The osteotomy wedge is morselized and placed at the osteotomy site. A compression screw is then placed within the hip screw in order to maintain compression at the non-union site

Low molecular weight heparin was used postoperatively for 10 days starting postoperatively from the 12th hour, for deep vein thrombosis prophylaxis. In each case, self-suction drains were used for one day.

Postoperatively, quadriceps exercises, knee and ankle mobilization and non-weight- bearing mobilization with crutches was started on the first day. Full weight bearing was restricted until there were signs of union at radiological evaluation. Radiography with anteroposterior views of the pelvis and hip as well as a frog leg lateral view of the hip, was performed every four weeks until bone union. Radiological union was defined as the absence of a fracture line and the appearance of trabeculae across the fracture. Neck shaft angle, fracture plane angle, and Pauwels type were assessed on postoperative radiographs. The postoperative radiographs were also evaluated for evidence of osteonecrosis of the femoral head. (Fig. 5,6). Patients were followed up clinically for pain weight bearing ability, ability to perform a straight-leg raise, leg-length discrepancy and hip range of motion. Clinical outcome was evaluated using the Harris Hip scores; a score of 90 to 100 was deemed excellent, 80 to 89 as good, 70 to 79 as fair, and < 70 as poor.

Statistical analysis (average, standard deviation, frequency) was carried out using SPSS (Statistical Software Package for the Social Sciences) 21.0 for Windows 7.

RESULTS

There were 11 male and five female patients, with a mean age of 33.8 (range: 19-59 years). Of the patients, nine had right and seven had left femoral neck fracture (Table 1). Eight of the patients had differences in preoperative extremity length and this difference was 2.1 cm on average (0.5-3 cm).

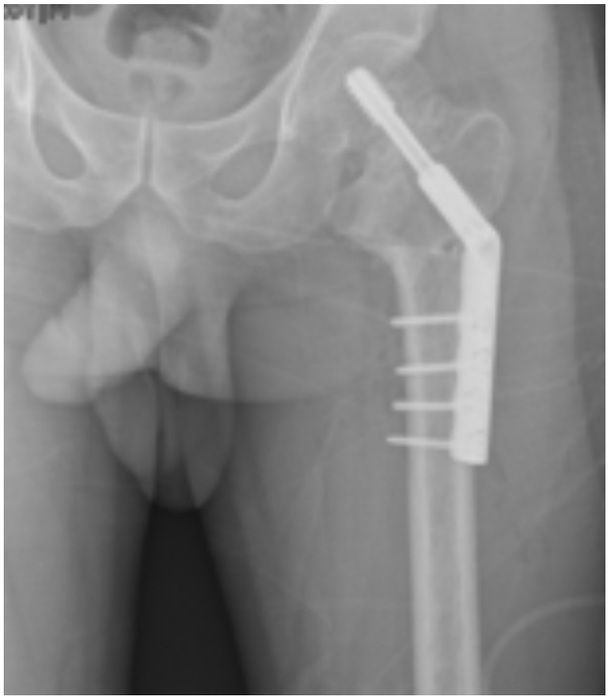

Fig. 5. — Postoperative x ray

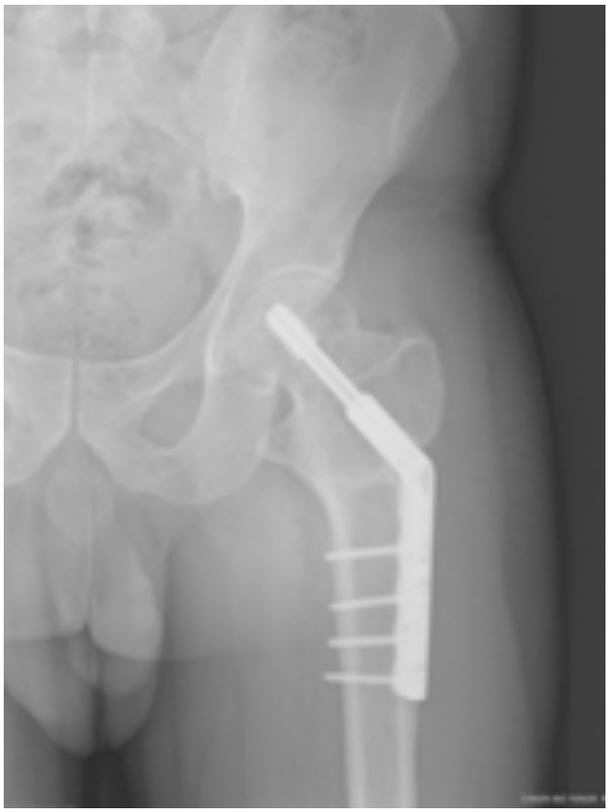

Fig. 5. — Postoperative 1 year x ray

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Table I. — Demographic profile of the patients

Case	Age and Sex	Etiology	Preop Pauwels Class	Postop Pauwels Class	Time between first and second op. (month)	Harris hip score	Healing Time (week)
1	42/M	TA	III	II	11	89	16
2	28/M	TA	III	I	7	90	18
3	30/M	SF	III	I	4	94	15
4	29/M	TA	III	I	12	85	15
5	20/M	FH	III	I	5	90	18
6	35/F	TA	III	II	6	88	20
7	22/M	SF	III	I	12	93	16
8	35/F	SF	III	I	9	94	20
9	48/M	FH	III	I	5	83	15
10	59/M	SF	III	I	7	91	18
11	51/M	SF	III	I	6	90	15
12	49/M	SF	III	II	9	86	20
13	24/M	FH	III	II	15	94	24
14	21/F	TA	III	I	6	87	16
15	19/F	TA	III	I	10	86	14
16	24/F	TA	III	I	3	85	16

(MALE:M, FEMALE:F, TA: Traffic Accident, Fall from Height, SF:Simple Fall)

The average operating time was 90 minutes (range: 70–120). The average estimated intraoperative blood loss was 600 ml (range 500–700). Intraoperative and postoperative blood transfusions were not required for the patients who were followed at the hospital for a mean duration of 4.5 days (range: 3-7 days) after the operation.

Union of both the fracture and the osteotomy site was achieved in 17.2 weeks (range: 14-24 weeks) in all patients based on radiographic criteria. The average Harris Hip Score increased from 26 (range 18 – 34) preoperatively to 85 (range 68 – 94) postoperatively. On radiographic examination, the average preoperative neck shaft angle was 121°(range 114 –128). Postoperatively, the average neck shaft angle increased to 140° (range 130 – 150). The average Pauwels angle decreased from 72o (range 62 – 80) preoperatively to 26° (range 20 – 50) postoperatively.

All patient's fractures were Pauwels type III preoperatively and 4 type II and 12 type I, postoperatively. One patient developed postoperative implant insufficiency and the implant was replaced. Union was achieved in this patient on week 12, following the second operation. Four of the patients had 1-cm shortening and three patients had pain that did not restrict active hip motions. No patients developed implant migration and displacement of osteotomy. Of the patients who were followed up for a mean duration of 3.1 years (range: 1-5 years), none developed avascular necrosis.

None of the patients had DVT, deep wound site infection and osteomyelitis. Only two patients had superficial wound site infection that recovered with antibiotherapy and local care. No statistically significant correlation could be established between the time interval from the first operation and the patient's age, and union.

DISCUSSION

Non-union is one of the most common complications following femoral neck fractures *(15,18,29)*. Several studies have reported that the

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incidence of this complication can be up to 30%. Such a rate is much higher particularly with displaced and vertical fractures *(12,24)*. Although re-surgery is inevitable in the treatment of patients developing non-union, there is no consensus on the type of surgery to be performed.

Methods, such as arthroplasty and arthrodesis, have been used to treat non-union as well as many refixation methods, such as muscle–pedicle bone grafting, vascularized bone grafting, valgus osteotomy, McMurray displacement osteotomy, fibular grafting and fixation with cancellous screws. Among these, arthroplasty is associated with good early outcomes; however, its late complications, such as several lifelong revisions, for a variety of reasons like mechanical insufficiency, means that when used in young patients it is problematic *(26,27)*. In patients undergoing arthrodesis, hip motions are lost, but the late outcomes in particular are very good, if union is achieved. However, union is not always achieved in hip arthrodesis and it is hard, particularly for young patients to accept this method *(9,15,27,30)*. Therefore, the emphasis is predominantly on refixation methods. Yet, there is no consensus on which approach is the best and under which circumstances *(5,9-11,14,26,27)*.

In non-union treatment refixation alone is difficult, due to impaired bone quality and decreased bone stock caused by previous implants. A study by Wu et al., in which refixation alone, was performed reported a 100% union rate in an average time of 4.6 months, in patients undergoing refixation alone in a series treated with DHS with and without osteotomy after femoral neck fractures. However, these results were not supported by a second study and they did not provide any information on the potential extremity length discrepancy after refixation *(31)*. Refixation can be combined with cortical or vascularized grafts. Very successful outcomes have been reported with this combination *(14,17,23)*. However, such studies did not evaluate the donor site morbidity. Additionally, the difficulty in performing vascularized graft and the prolonged operation time, are disadvantages.

Another alternative method is osteotomy. This method eliminates the mechanical and physiological causes of non-union *(3,16,24,28)*. Two types of osteotomy have been used in the past. One is the McMurray osteotomy, which is performed just above the trochanter minor and the other is the Shanz type osteotomy, which is performed below the trochanter minor *(3,24)*. Introduced by Shanz, abduction angulation osteotomy was developed by Pauwels.

Pauwels asserted that the shear forces caused by mechanical factors, due to the increased angulation in the vertical plane of fracture line, are increased and therefore union is more difficult in high-energy fractures. The straightforward and logical foundation of Pauwels' osteotomy is to increase the compression forces on the fracture line by minimizing shear and tensile forces by means of an osteotomy, since biomechanical factors are highly important effective in the healing of femoral neck fractures. Furthermore, the extremity shortened with osteotomy elongates by approximately 2 cm through excessive valgisation of the proximal femur, and the difference between extremities is closed *(3,29)*. For these reasons, Pauwels applied subtrochanteric valgus osteotomy to type 3 fractures and non-union cases, and recommended using this method *(3,21)*. The osteotomy suggested by Pauwels, and its modifications, have been tried several times and successful outcomes have been reported after using osteosynthesis with wedge plates *(1,21,23,25)*. Furthermore, the use of a graft is no longer mandatory, due to the biomechanical advantages of osteotomy *(21)*.

The two separate studies that have been conducted with the largest series to date obtained similar results. In these studies by Marti et al and Zehi et al., osteosynthesis was performed using a blade plate after intertrochanteric valgus osteotomies. In the series by Marti et al, 43 of the 50 non-unions healed. Preoperatively, twenty-two hips had avascular necrosis, with only three of these cases progressing to collapse *(21)*. In the series by Zehi et al, 41 patients had only one non-union, with 16 cases developing avascular necrosis *(32)*. Another study was conducted by Necmioglu et al. This study achieved union in all of the 14 patients, most of whom had preoperative avascular necrosis findings *(25)*. Since wedge plates provide excellent rotational stability and allow the lateralization of the femoral

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shaft, all of these studies have used these plates *(21,25,32*).

Osteosynthesis with dynamic hip screws is an established method that has long been used following hip fractures and, unlike the wedge plate, can be successfully performed by almost every orthopedist. Besides, this system may accelerate union by applying compression on the fracture site during the operation. Although this system cannot provide such good rotation as wedge plates, there is still partial rotational stability, due to the fibrous tissue developed after the previous operation *(21,31,32)*.

Wu et al used DHS for fixation in femoral neck nonunion cases *(33)*. The authors compared the outcomes of patients who had DHS without osteotomy and those who had DHS after subtrochanteric valgus osteotomy. The medication for an osteotomy was based on the amount of shortening. An osteotomy was done only with leg shortening of more than 1.5 cm. In both groups, all femoral neck non-unions realed. Wu et al's series demonstrates the successful use of dynamic hip screws only in the treatment of femoral neck non-unions when there is minimal leg length discrepancy *(33)*.

Osteotomy has two potentially important disadvantages. After the osteotomy, valgus orientation of the proximal femur increases contact pressures on the head. This may cause degenerative disease or progressive AVN *(32)*. Valgus positioning may also lead to a decrease in functional results and a persistent limp. The early postoperative outcome is good, but degenerative changes may develop over the following years *(20,24)*. Another disadvantage is the creation of a second potential site for non-union: the osteotomy site. Additionally, osteotomy may make future arthroplasty difficult *(1,3,21,28)*.

In our series, no case of osteonecrosis has been found during follow-up and the union of both the fracture and the osteotomy site was achieved in all patients undergoing osteotomy. Two of our patients were walking with a limp and four patients had 1-cm extremity length discrepancy. Additionally, postoperative Harris Hip Scores showed substantial improvement over the preoperative scores.

Osteotomy should not be used in fractures with severe bone loss and in cases with a severe femoroacetabular discrepancy. For older patients, arthroplasty remains a good option, yet osteotomy can also be successfully performed in these patients. Furthermore, osteotomy should be considered in young patients, even in the presence of radiographically established AVN of the femoral head or resorption of the neck *(21,31,32)*.

The limitations of the present study are the retrospective design, the limited number of patients, the wide range of age and short duration of follow-up to investigate hip osteoarthritis. Without these limitations, prospective evaluation with a control group and a larger sample size might provide more insight, and may be possible in future studies.

CONCLUSION

Although non-union problems following femoral neck fractures are common, the primary objective is to preserve the hip, by seeking alternative methods, specifically in young patients, and considering that the femoral neck can usually remain viable. Therefore, alternatives such as valgus osteotomy, which enables union by solving mechanical issues and allows patients to live with their own bones, have long been in use and successful. However, osteosynthesis with wedge plates is a method not familiar to many orthopedists and this might have resulted in decreased utilization rates of method. We performed osteosynthesis with DHS, a procedure with which almost all orthopedists are familiar, and achieved union of all these fractures. Therefore, we believe that valgus angulation osteotomy, which is a liberating operation particularly for young patients, should be used as a rescue method that can be performed very successfully combined with DHS-osteosynthesis.

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