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PŮVODNÍ PRÁCE

Direct Radiography Following Fracture Reduction Improves the Reliability of Pauwels Classification

Rtg vyšetření bezprostředně po repozici zlomeniny zvyšuje spolehlivost Pauwelsovy klasifikace

M. KUMBARACI[1] , A. TURGUT[1], T. BACAKSIZ[2], G. ILYAS[3], E. BILGIN[1], Ö. KALENDERER[1]

[1] Tepecik Training and Research Hospital Izmir, Turkey
[2] Akcakale State Hospital Sanliurfa, Turkey
[3] Mustafa Kalemli Tavsanli State Hospital Kutahya, Turkey

ABSTRACT

PURPOSE OF THE STUDY

Pauwels classification system is widely used to classify the femoral neck fractures. Even its widely usage there are severals debates about its reliability. After the femoral neck fracture occured the lower extremity rotates externally and this external rotation deformity could lead to misevaluation of Pauwels angle at the initial radiographs. The purpose of our study is to investigate whether the reliability of Pauwels classification increases after reduction of femoral neck fractures.

MATERIAL AND METHODS

Two power point presentation was prepared with 117 slides that include antero-posterior radiographs of each femoral neck fracture. The first one included preoperatively taken radiographs and the second one included early postoperatively taken radiographs. Eight observers evaluated these radiographs and they classified the fractures according to Pauwels classification system. After 3 months, the order of the slides were changed for each presentation and the observers were asked to evaluate the radiographs again. Intraclass correlation coefficient values were calculated for evaluation of inter- and intra-observer reliability.

RESULTS

The mean intra-observer agreement of preoperative evaluation was 0.406 (0.071–0.626) and the interobserver agreements were 0.263 (0.197–0.342) and 0.359 (0.287–0.447), respectively. The intra-observer agreement of postoperative evaluation was 0.508 (0.393–0.757), inter-observer agreements were 0.427 (0.353–0.509) and 0.431 (0.356–0.513), respectively. According to preoperative and postoperative evaluations, 6 of 8 observers' intra-observer agreements were found to be increased and the remaining 2 decreased. Interobserver reliability was improved from poor to fair-good values after evaluating the reducted fracture radiographs.

DISCUSSION

Femoral neck fractures(FNF) are common and anatomical reduction and internal fixation are preferred as a treatment option in young people and patients have good bone quality. Pauwels classification system is used for classify the FNF based on the shearing angle of the fracture line. As this angle increases, the fracture becomes unstable and nowadays stronger fixation devices are preferred for unstable fractures. Therefore, misevaluation of the fracture can lead to wrong treatment method selection. Non-optimal X-rays taken in the emergency rooms may cause misinterpretation of femoral neck fractures according to Pauwels classification system. We hypothized that the reliability of this classification system could be improved after reduction of the fracture.

CONCLUSIONS

Our study showed that classifying the femoral neck fracture according to Pauwels classification system is more confidential after the reduction, however we can not state that it's reliability is adequate.

Key words: femoral neck fracture, Pauwels classification, reliability, inter-observer, intra-observer.

INTRODUCTION

Femoral neck fractures are commonly seen in orthopaedic trauma and these injuries are usually treated operatively (11). In elderly, hemiarthroplasty and total hip arthroplasty are options for treatment. In contrast, in relatively young patients (<60 years old) with good bone quality anatomical reduction and internal fixation is the preferred method (13). Several complications such as nonunion, avascular necrosis, varization and shorthening of the femoral neck can be seen after the internal fixation (4). Classifying these fractures is crucial for determining the treatment options and predicting the possible complications. There are mainly three classification systems that are being used to classify these injuries. Pauwels classification which was firstly described in 1935 is one of them and widely used by the orthopaedic surgeons. This classification system is based on the angle between the fracture line and the horizontal plane. This system consists of 3 grades according to the fracture

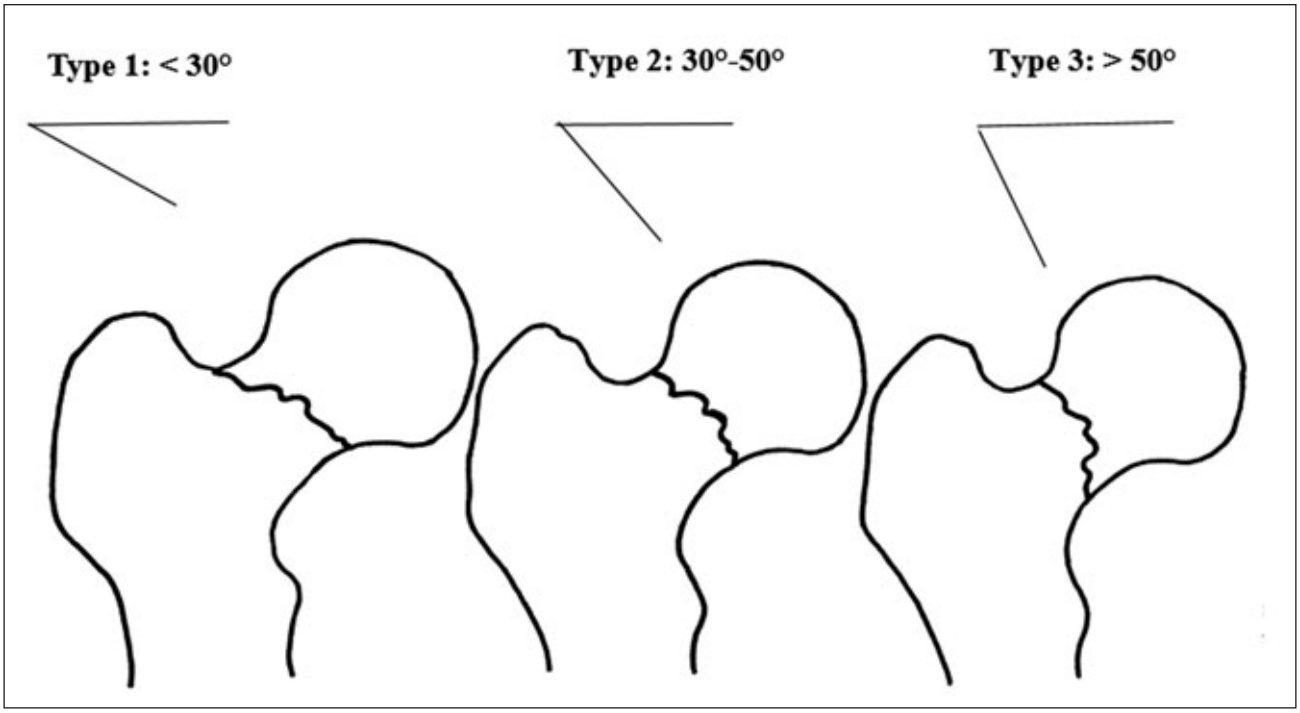

Fig. 1. Schematic drawing of Pauwels classification.

line's orientation. Type 1; up to 30°, type 2; between 30–50° and type 3; 50° and more (1, 14). Pauwels et al. suggested that more vertical the fracture line, the higher risk of non-union, malunion and the need of reoperation (14). One should be more carefull when treating the fractures which are oriented more vertically. Eventhough Pauwels classification system is widely used there are several debates about its reliability (2, 7, 15–19). The misevaluation of the fracture line and the mismeasurement of the Pauwels angle is affecting the Pauwels classification's reliability, negatively (19). Difficulty in decision making between type 2 and 3 fractures could lead to false choice of implant. The other classifications used for grading femoral neck fractures are Garden and Arbeitsgemeinschaft Für Osteosynthesefragen (AO) classifications (6, 12).

After femoral neck fracture, associated lower extremity externally rotates and initially taken radiographs are not suitable for identifying the orientation of the fracture line because of this external rotation deformity as well as possible abduction and adduction deformities. We think that most important reason for the lower reliability of the Pauwels classification system compared to the other ones is this external rotation deformity. Although in 1961, Garden stated (6) that evaluation of the Pauwels classification should be more reliable after reduction of the fracture, the effect of the reduction on reliability was never studied. Our study question was whether the reliability of the Pauwels classification system can be increased after reduction of the fracture with correcting this externally rotation deformity. We hypothesized that reliability of the Pauwels classification system increases after evaluating the radiographs of reducted fracture.

MATERIAL AND METHODS

The patients with femoral neck fracture who were treated with closed or open reduction and internal fixation with cannulated screws between January 2009 and January 2017 were reviewed retrospectively from the hospital's digital archieve. Local ethical committee aproval was obtained for this study. There were totally 212 patients. The patients who were younger than 18 years old (22 patients) and patients with a poor quality preoperative and/or postoperative radiographs (73 patients) were excluded from the study. Finally, 117 patients with a good quality preoperative and early postoperative radiographs were included into the study. Preoperatively and early postoperatively taken antero-posterior (AP) radiographs of the fractured hips were saved as 'Joint photographic Experts Group (JPEG) format from the Picture Archiving and Communication System (PACS). There was not any standardization for preoperatively taken radiographs but postoperatively taken radiographs were taken while the hip was 15° internally rotated. Two Microsoft Powerpoint presentations (PPT) had been prepared by a surgeon who was not included as an observer in the study with JPEG images of each patients. The first one included preoperatively taken radiographs and the second one included early postoperatively taken radiographs as 117 slides. The presentations were evaluated by eight observers who were experienced in orthopaedic trauma surgery for two to seventeen years. The Pauwels classification's schematic drawing was given to the observers with these two PPTs for evaluation (Fig. 1). Each observer was asked to evaluate the radiographs in two weeks. After three months

Table 1. Intra-observer reliabilities of preoperatively and postoperatively taken radiographs evaluations according to the Pauwels classification system

	Preoperative ICC scores	Postoperative ICC scores
Observer 1	0.540 (0.398–0.657)	0.757 (0.668–0.825)
Observer 2	0.626 (0.502–0.725)	0.655 (0.537–0.747)
Observer 3	0.071 (-0.111–0.249)	0.393 (0.229–0.536)
Observer 4	0.485 (0.333–0.612)	0.455 (0.298–0.587)
Observer 5	0.496 (0.346–0.621)	0.407 (0.244–0.547)
Observer 6	0.300 (0.126–0.456)	0.415 (0.253–0.554)
Observer 7	0.262 (0.085–0.423)	0.500 (0.351–0.624)
Observer 8	0.474 (0.320–0.603)	0.485 (0.333– 0.612)
Mean (min–max)	0.406 (0.071–0.626)	0.508 (0.393–0.757)

ICC – Intraclass Correlation Coefficient, min – minimum, max – maximum

the first evaluation, the orders of the slides were changed for each two PPTs. The observers were asked to evaluate these newly prepared PPTs in two weeks again.

Statistical analysis was performed by calculating the intraclass correlation coefficient (ICC) value using SPSS 17 statistical software for inter- and intra-observer reliability (5, 9). ICC values were calculated instead of Cohen's kappa (5) for the evaluation of inter-observer reliability because there were more than 2 observers. The ICC value greater than 0.75 was evaluated as excellent agreement, 0.40–0.75 was fair to good and below 0.40 was poor (17).

RESULTS

The average age of the study population was 47±13.6 (18.6). Forty-two (35.9%) of the patients were female. One hundred and thirteen (96.5%) of the fractures were fixed with 3 cannulated screws (CS), three of them (2.5%) with four CS and only one of them (1%) with Dynamic Hip Screw (DHS). It was observed that 101 of the fractures (86.3%) were anatomically reduced. The mean intra-observer agreement of preoperative evaluation was 0.406 (0.071–0.626) (Table 1) and the inter-observer agreements were 0.263 (0.197–0.342) and 0.359 (0.287–0.447), respectively (Fig. 2). The intra-observer agreement of postoperative evaluation was 0.508 (0.393–0.757) (Table 1), inter-observer agreements were 0.427 (0.353–0.509) and 0.431 (0.356–0.513), respectively (Fig. 2). According to preoperative and post-operative evaluations, 6 of 8 observers' intra-observer agreements were found to be increased and the

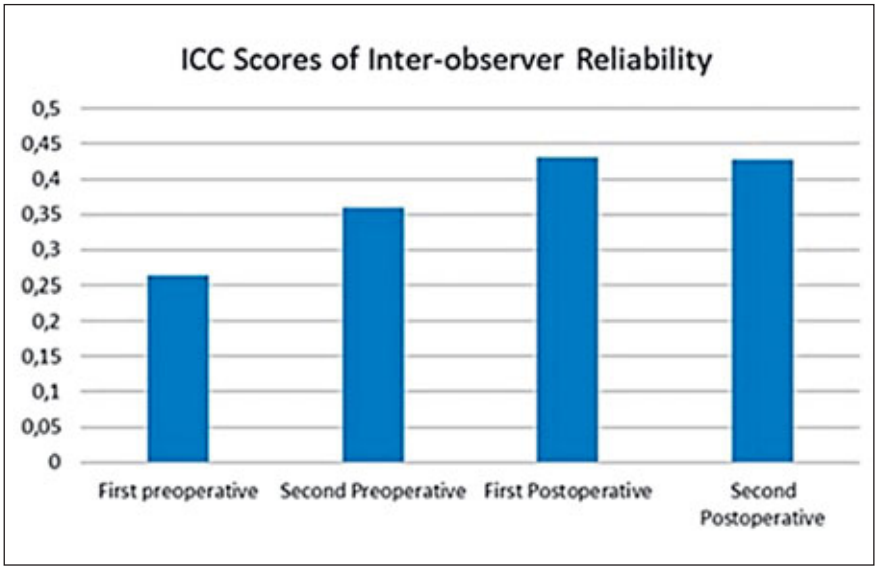

Fig. 2. ICC (Intraclass Correlation Coefficient) scores of inter-observer reliability for each evaluation.

Table 2. Changes of the observers' decisions about the Pauwels grades

	First evaluation		Second evaluation		Pauwels 2 to 3	
	Pauwels grade increased (n)/(%)	Pauwels grade decreased (n)/(%)	Pauwels grade increased (n)/(%)	Pauwels grade decreased (n)/(%)	First evaluation (n)/(%)	Second evaluation (n)/(%)
Observer 1	17/14.5	13/11.1	22/18.8	13/11.1	14/11.9	7/5.9
Observer 2	12/10.2	8/6.8	15/12.8	9/7.7	9/7.7	9/7.7
Observer 3	34/29.1	18/15.4	27/23.1	26/22.2	15/12.8	21/17.9
Observer 4	34/29.1	10/8.5	27/23.1	11/9.4	23/19.6	22/18.8
Observer 5	32/27.3	18/15.4	21/17.9	15/12.8	31/26.5	17/14.5
Observer 6	13/11.1	23/19.6	12/10.2	10/8.5	11/9.4	7/5.9
Observer 7	37/31.6	15/12.8	22/18.8	24/20.5	24/20.5	16/13.6
Observer 8	30/25.6	18/15.4	25/21.4	15/12.8	9/7.7	13/11.1
Meanly (%)	18.7	13.1	15.4	13.1	14.5	11.9

remaining 2 decreased (Table 1). Inter-observer reliability was improved from poor to fair-good values after evaluating the reducted fracture radiographs (Fig. 2). Changes of the observers' decisions about the Pauwels grades are shown in table 2.

DISCUSSION

Classification systems are useful methods that creat a common language between the physicians and help to make investigations. They are used for making a decision on an adequate method of treatment and they can give some clues about possible complications. Adequate treatment of femoral neck fractures is crucial because of possible morbidities for both internal fixation and arthroplasthy. Even the Pauwels classification system is widely used there are several debates about its reliability (2, 7, 15—19). We hypothized that the basis of these debates and misevaluations were the external rotation deformity of the femoral shaft. So the reliability of this classification system could be improved after reduction of the fracture. Our results showed that the reliability of the Pauwels classification improved from poor to fair-good values by evaluation of the postoperatively taken radiographs.

van Embden et al. (18) evaluated 100 anterior-posterior and lateral preoperatively taken radiographs of femoral neck fractures and they classified these radiographs according to the Pauwels classification system. In this study inter-observer agreement was found to be κ:0.31 for all observers, 0.38 for surgeons and 0.27 for residents which concluded that reliability of the classification system was fair. They stated that Pauwels classification system is unreliable and for this reason it's usage should be avoided (18). Gaspar et al. compared AO group, AO subgroup, Garden and Pauwels classification systems of femoral neck fractures. According to Pauwels system they found inter-observer agreement was 0.19 and intra-observer agreement was 0.38 and they did not recommend using the Pauwels classification system for femoral neck fractures (7).

Turgut et al. (17) compared the classification systems for adult femoral neck fractures and they also evaluated surgeons' experience on intra- and inter-observer reliability. In their study; inter-observer agreement of whole observers' was found to be κ:0.24 for the first review and κ:0.18 for the second review of Pauwels classification. ICC value for intra-observer reliability was meanly 0.46 (fair to good). The highest kappa (Fleiss) values were found in the middle experienced group for both two reviews (0.23 and 0.24). According to these data they could not state that experience is important for inter-observer reliability of Pauwels classification (17). This study had also demonstrated that reliability of the Pauwels classification system was not enough to make accurate decision.

Our study demonstrated similar findings with all previously mentioned studies. Inter-observer reliability of the Pauwels classification was poor with traditionally evaluation of preoperatively taken radiographs. However, it was observed that this reliability is improved with the evaluation of the radiographs after the reduction. This was an important finding since our hypothesis was so.

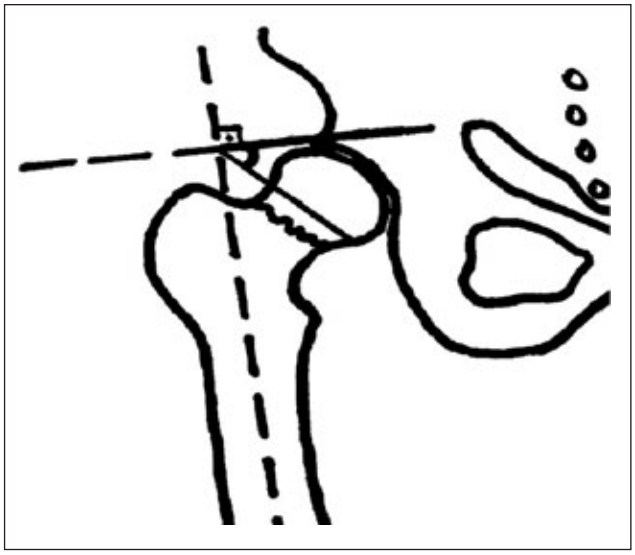

Fig. 3. The modified Pauwels method uses the central line of the femoral shaft as a reference and then draws a perpendicular line. The modified Pauwels angle could be measured as the angle between this perpendicular line and the fracture line (19).

Pauwels classification system is based on the shearing angle of the fracture line. This angle consists of 2 lines; horizontal line and the fracture line of the distal fragment. However, these lines easily change depending on the patients' and the limb's position (1, 14). The abduction, adduction, internal and external rotation positions of the leg could alter the measurements of the Pauwels angle (19). The versatility of these lines on the anteroposterior view could make this classification system unreliable. In the literature there are 2 studies which tried to standardize the measurement of the shearing angle. Wang et al. (19) described the modified Pauwels measurement method which was based on the postoperative X-rays (Fig. 3). They used the central line as a guide line in the femoral shaft and they drawed a visionary line which was perpendicular to guide line. The modified Pauwels angle was measured as the angle between the perpendicular line and the fracture line. In their study they investigated inter- and intra-observer agreements and they classified the fractures according to Pauwels classification and modified Pauwels classification. They found fair intra-observer reliability (κ:0.32) and poor inter-observer reliability (κ: 0.18) with using the traditional measurement method and they obtained a good intra-observer agreement (κ:0.68) and inter-observer agreement (κ:0.63) for the modified method. They claimed that modified Pauwels method is reliable and useful method which could predict the outcomes of the femoral neck fractures (19). In the second study Collinge et al. (3) investigated the fracture morphology of high shear angle (>50) in young adult patients. Only vertical fractures were included the study and they measured the

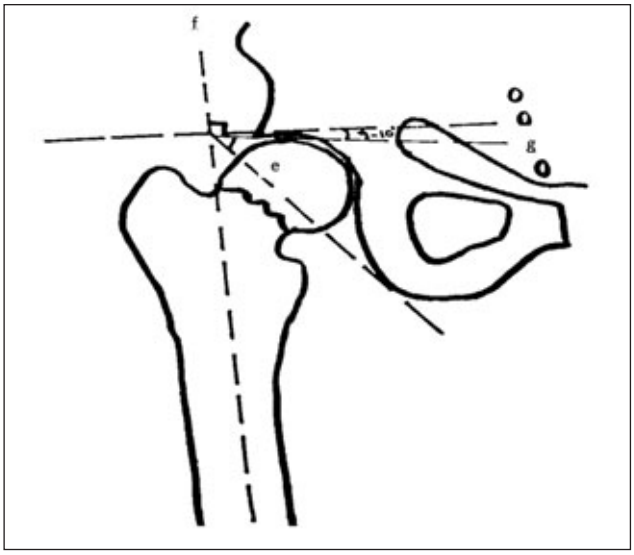

Fig. 4. Measurement of the Pauwels angle. Angle e represents the Pauwels angle; f is the line of the anatomic axis of the femoral shaft; g is the imaginary line which is equal to the horizontal line; and h is the line of fracture (16).

Pauwels angle on preoperative, postoperative X-rays and pre-operative computed tomography (CT) by using modified Pauwels method. Pauwels' angles averaged 60.5° on preoperative radiographs (range, 51–80°), 63.6° on postoperative radiographs (range, 52–80°), and 68.6° on preoperative CT. They did not evaluate the inter- and intra-observer agreements. This study demonstrated that the inclination line of the femoral neck fracture is underestimated with evaluating preoperatively taken radiographs. Shen et al. (16) claimed that this modified method had some defects. In this method the imaginary line is equal to horizontal line. Between anatomic axis and mechanical axis, there is 6–7° intersection angle. Mechanical axis intersects the gravity line with 3° angle and horizontal line is perpendicular to the gravity line. For these reasons there is 80–81° angle between anatomic axis of femoral shaft and imaginary line and they should not be perpendicular to each other (Fig. 4).

Several clinical studies investigated optimal fixation method for Pauwels type 3 femoral neck fractures (8, 10, 11, 13). Liporace et al. evaluated the treatment results of femoral neck fractures with high shear angle (>70) with different internal fixation methods. They found non-union rates was 19% for fractures treated with CS alone and 8% for those treated with fixed-angled device (10). Hou et al. compared three CS and DHS for communited femoral neck fractures. They claimed that DHS was superior to CS for the treatment of the communited femoral neck fractures which provides earlier weight-bearing, faster fracture union and better hip functions (8). All of these studies showed that classifying the femoral neck fractures properly according to Pauwels classification system is crutial for selecting appropriate implant. We suggest that femoral neck fractures might be classified after fixing the fracture with temporarily Kirchner wires and than fixation methods might be chosen (Fig. 5).

There are several limitations of our study. First of all, it is a retrospectively designed study. The number of the observers and evaluated radiographs could be more. In our study, the traditional method was used instead of modified Pauwels angle measurement method. Usage of new measurement method of Pauwels angle could improve the reliability of Pauwels classification system.

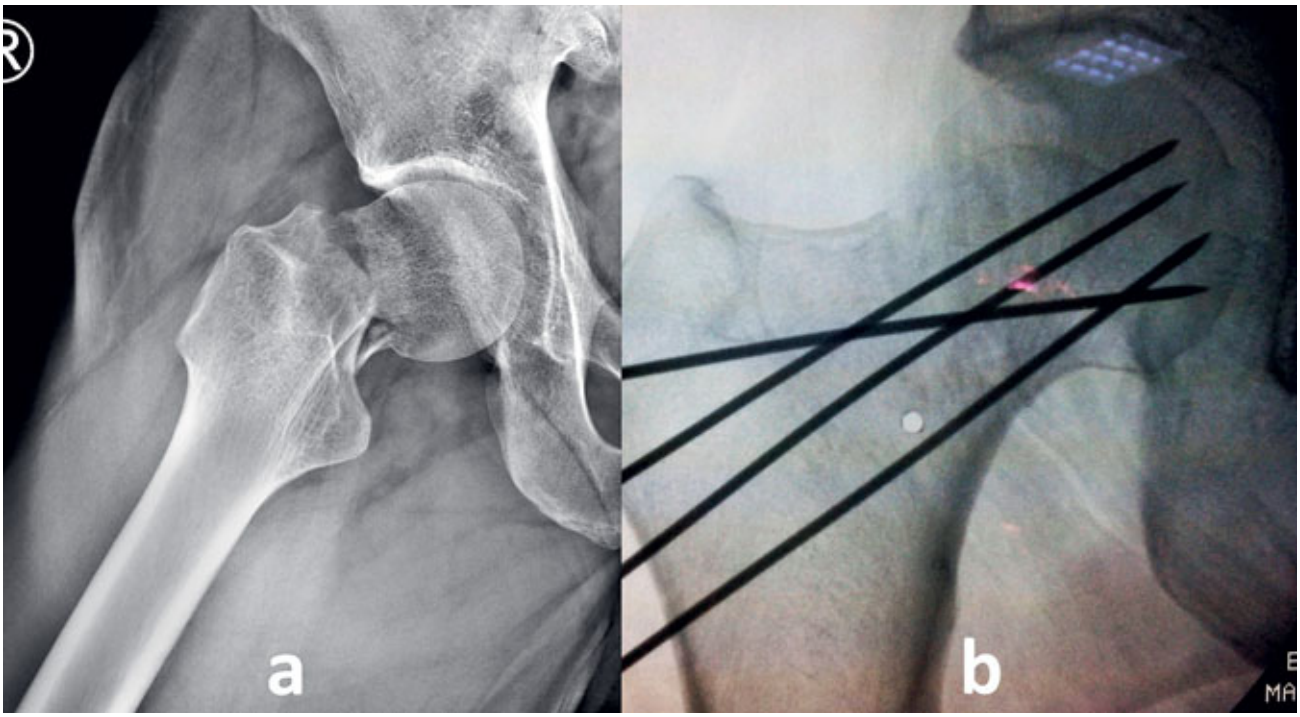

Fig. 5. a – preoperatively taken radiograph of the fracture, b – intraoperatively fluoroscopic view after the reduction and temporarily fixation with Kirschner wires.

Another important limitation is that there was no standardization for preoperatively taken radiographs.

CONCLUSIONS

Our study showed that classifying the fracture according to Pauwels classification system is more confidential after the reduction, however we can not state that it's reliability is adequate. We suggest that femoral neck fractures might be classified after fixing the fracture with temporarily Kirchner wires and than fixation methods might be chosen. There has to be more than one implant options in the operation room since one can change his/her choice of the implant after evaluating the fracture after reduction.

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Corresponding author:
Mert Kumbaraci, MD
Orthopaedic Surgeon
Tepecik Training and Research Hospital
Orthopaedic and Traumatology Department
35110 Yenisehir-Izmir, Turkey
E-mail: kumbaracimert@hotmail.com