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Clinical analysis of internal fixation femoral neck fractures with two or three cannulated screws

Клиничка анализа унутрашње фиксације прелома врата бутне кости
применом два или три канулирана завртња

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SUMMARY

Introduction/Objective Angular stability and dynamic fixation are key factors to successful healing of femoral neck fractures. We evaluate the efficacy of internal fixation of femoral neck fractures with two parallel self-tapping antirotation screws (SAF) compared to standard, three cannulated cancellous screws (CCS) fixation.

Methods One-hundred fractures were retrospectively analysed, divided in two groups in which two SAF screws were used in parallel (n=50) or three standard AO screws in an inverted triangle configuration (n=50). The groups were compared with operation time, time of consolidation, femoral neck shortening, Harris score and reoperation rates.

Results SAF parallel fixation group of patients achieved consolidation rate of 86% compared to 74% in CCS fixation group, without statistically significant difference between the examined groups ($p > 0.05$). Dynamization of implants was significantly positively correlated with the fracture healing time in both examined groups (SAF: $r = 0.324$, $p = 0.025$; CCS: $r = 0.572$, $p = 0.001$), with significantly shorter healing time in SAF patients – on average 15 weeks (15.02 ± 1.44) in relation to the CCS group of patient - 19 weeks (19.81 ± 2.94) ($X^2/z = 7.048$, $p < 0.001$). There was no statistically significant difference in the Harris score and reoperation rate among the study groups ($\chi^2 = 2.44$, $p = 0.487$; $\chi^2 = 0.500$, $p = 0.696$).

Conclusion Our results suggested that dual parallel fixation (SAF) is simpler, less invasive and it demands less time for performing. It is not inferior to fixation with 3 screws, from the point of biomechanics, possible complications, healing and functional recovery.

Keywords: femoral neck fractures; bone union; internal fixation

САЖЕТАК

Увод/Циљ Ангуларна стабилност и динамичка фиксација су кључни фактори за успешно зарастање прелома врата бутне кости. Циљ ове студије је процена ефикасности унутрашње фиксације прелома врата бутне кости са два паралелна самонарезујућа антиротациона (САФ) завртња у односу на три стандардна АО завртња.

Метод Ретроспективно је анализирано 100 прелома врата бутне кости, који су хируршки збрињавани са два САФ завртња (n = 50) или три стандардна АО завртња у конфигурацији обрнутог троугла (n = 50). Упоредивана је дужина операције, време зарастања прелома, степен скраћивања врата бутне кости током консолидације прелома, крајњи функционални резултат мерен Харис скором и стопа реоперације.

Резултати У групи у којој се користила дуална (САФ) паралелна фиксација, консолидација прелома је остварена у 86% случајева у односу на 74% у групи са три канулирана завртња, без статистички значајне разлике међу испитаним групама ($p > 0.05$). Динамизација имплантата значајно позитивно је корелирала са временом зарастања прелома у обе испитиване групе (САФ: $p = 0.324$, $p = 0.025$; АО: $p = 0.572$, $p = 0.001$), са значајно краћим временом зарастања у групи САФ пацијената - просечно 15 недеља (15.02 ± 1.44) у односу на АО групу пацијената - 19 недеља (19.81 ± 2.94) ($X^2/z = 7.048$, $p < 0.001$). Према Харис кук скору и стопи реоперација, није примећена значајна разлика између група ($\chi^2 = 2.44$, $p = 0.487$; $\chi^2 = 0.500$, $p = 0.696$).

Закључак Резултати указују да је дуална паралелна фиксација (САФ) једноставнија, мање инвазивна и захтева мање времена за извођење. Није инфериорна у односу на фиксирање са три завртња, са становишта биомеханике, могућих компликација, зарастања и функционалног опоравка.

Кључне речи: унутрашња фиксација; прелом врата бутне кости; зарастање

INTRODUCTION

Femoral neck fractures include injuries involving the area between the head of the femur and the intertrochanteric line and account for nearly half of all hip fractures, increasing

exponentially with age [1]. The specific intracapsular environment with vulnerable vascular supply, and burden some biomechanics of the hip, contribute to the high complication rates seen after osteosynthesis of these fractures [2].

Internal fixation is frequently used for undisplaced fractures and for displaced intracapsular fractures in which preservation of the femoral head is preferred or the patient with poor pre-morbid conditions for arthroplasty [3, 4]. Traditionally intracapsular femoral neck fractures are operatively treated with three cannulated cancellous screw, but controversy remains over what the ideal number and correct position of screws for treating these fractures should be [5, 6].

However, the outcomes after conventionally inverted cancellous three screw fixation of femoral neck fractures have not been uniformly positive and the rates of revision surgery ranging from 8% to 27% [7]. One of the main reasons for such poor outcomes is reflected in a more technically demanding procedure in terms of fracture reduction and correct placement of screws. A simpler technique of placing only two parallel screws – one higher and the other lower in the femoral neck – may be a suitable alternative to improve complication rates of surgical treatment of femoral neck fractures in properly selected patients.

The primary objective of our trial was to evaluate the clinical outcome of internal fixation of femoral neck fractures by double screws versus three cancellous screws fixation in skeletally mature patients.

METHODS

After Institutional Review Board approval (ref. no. 12-2466-12, approval date 9 March 2015) we retrospectively reviewed data from January 2014 to January 2017 from the Clinic of Orthopedics and Traumatology, Clinical Center in Nis. The study included a series of 100 patients with femoral neck fractures treated by the same group of surgeons. A group of 50 patients with femoral neck fractures were treated surgically with two parallel inserted self-tapping anti-rotational screw fixation (SAF group), while the other group of 50 patients surgically were treated using the multiple cancellous screw fixation method with three

cannulated cancellous screws (CCS group). Data were collected and compared retrospectively in both groups. Patient was randomized using random allocation software [8]. The patients were not blinded to their treatments. All patients were followed up until fracture union or a revision surgery was performed. No patient was lost by the end of the first year follow-up.

The inclusion criteria were all patients who had either an undisplaced fracture, or a displaced femoral neck fracture with ASA score range from 1 to 3, who walked independently prior to the fracture, in the absence of hip osteoarthritis. We excluded from the study patients with pathological femoral neck fractures, open femoral neck fractures, femoral neck fractures in skeletal immaturity patients, polytrauma patients (ISS>16) with ipsilateral fractures of femoral neck and shaft fractures and patients older than 65 years who had a severe concomitant medical condition (Grade 4, 5 American Society of Anesthesiologist Score).

Fracture management

In all selected cases the surgery was performed either in spinal or general anesthesia, with patients positioned supine on a traction table using the technique of closed reduction under C-arm control with manual traction and internal rotation of the injured extremity (Whitman's maneuver). If closed reduction was not satisfied after two attempts, open reduction through Watson-Jones approach was carried out. In our clinical practice, for the last 15 years, we predominantly used for osteosynthesis of femoral neck fractures, double self-tapping anti-rotational screw fixation method (SAF) from a domestic supplier (D.O.O. Traffix, Serbia). Anti-rotational self-tapping cannulated screw is made by medical steel 316LVM, body diameter screw of 7.2 mm, with threads thickness of 9 mm with a threads length of 16 mm and self-tapping tip (Figure 1(B)).

The first group of 50 patients, in our study, underwent surgery with dual SAF cannulated implant from a domestic supplier (D.O.O. Traffix, Serbia). Anti-rotational self-tapping cannulated screw is made by medical steel 316LVM, body diameter screw of 7.2 mm, with threads thickness of 9 mm with a threads length of 16 mm and self-tapping tip. The second group (CCS) of patients consists of other 50 patients with femoral neck fractures

surgically treated by using standard 6,5 or 7.3 mm three cannulated cancellous screws (figure 1 (A,B, C,D)). The SAF screws are designed to adjust to the load to which they are exposed and, on the other hand, to minimally injure bone tissue. Derotation compression of the fragment is achieved by parallel position of the SAF screws. These characteristics make the concept distinctive by itself. The tip of each screws was driven into head of femur to within 5 mm, approximately, from the subchondral bone plate (figure 2).FIGURE 2

On the other hand, three cancellous screws, in most cases, were placed in the configuration of an inverted triangle, respecting the principles of three-point fixation (3 Point Principle) [9].

Assessment methods

Radiographic parameters

Before internal fixation, based on radiographs, the fracture classification according to Pauwel's and Garden classification was performed. Pauwels type II and III fractures ($\geq 50^\circ$) were considered unstable and Garden III or IV fractures were considered displaced. Acceptable reduction parameters have been defined as a neck shaft angle between 130 and 150 degrees, less than 15 degrees of valgus with no varus angulation, and 0–15 degrees of lateral angulation [10]. Intraoperative reduction assessments were graded as anatomical, acceptable or poor in both groups of patients. Preoperative and postoperative data were recorded, including age, type of fracture, degree of posterior comminution, surgical timing, duration of surgery, and final outcomes.

Functional outcome assessments and complications

Postoperatively, all patients received antibiotic prophylaxis for 48 h and deep vein thrombosis prophylaxis for 3 weeks. Postoperatively, sitting was encouraged at the first day, non-weight-bearing ambulation with the aid of a walker frame was allowed after 1 or 2 weeks as long as the pain was tolerated. Patients were encouraged to partial weight bearing 6 weeks

after the operation. After hip X ray confirmation that fracture healed, full weight bearing was allowed. Postoperative radiographs were assessed until the end point was reached, defined as fracture consolidation, collapse of the femoral neck, loss of reduction that necessitated reintervention, necrosis of the head or pseudarthrosis of the neck, with a minimum period of six months elapsed from the time of the fracture. As an predictor of poor outcome, the influence of posterolateral comminution on healing time and stability of fixation was tested. The sliding length of the lag screws after fracture consolidation was measured by comparing the immediate postoperative and final AP radiographs.

The complete functional recovery of the patient after the minimum of one-year follow-up was verified in our study. The values obtained by filling in the questionnaires of Harris's hip score scaled from 1 to 100. After 12 months follow up check, all patients in both groups were studied for the functional outcome, as well as the effect of femoral neck shortening on gait pattern and muscle strength and reoperation rate was recorded.

Data analysis

Statistical analysis was performed with SPSS® Version 16.0 for Windows® (SPSS Inc, Chicago, IL). Baseline and outcome variables were compared between the investigated groups. Proportions and means among groups were compared using either the Chi-square or Fisher's exact test and Student's t test, respectively. Statistical significance was set at $p < 0.05$.

RESULTS

A total of 100 patients with undisplaced and displaced femoral neck fractures were included in this retrospective study. Their baseline socio-demographics data and significance in prevalence, in relation to the treatment groups (SAF vs. CCS), are shown in the Table 1.

The mean operative time for the fixation with two cannulated screws was significantly shorter by approximately 14 min (52.89 min vs. 39.17 min, $p < 0.0001$, unpaired t-test)

(Figure 3). Intraoperative blood loss and average fluoroscopy time were similar in both groups, with no significant difference ($p = 0,75$; $p = 0,62$).

Statistical analysis of the data found that the majority of patients in the overall population achieved anatomical type of fracture reduction or acceptable one, without statistical significance ($p = 0.490$), as shown in Table 2.

The SAF group of patients had union rate of 86%, consolidation was observed in 43 of the fifty fractures. In the group which was made standard methods of treatment, consolidation was observed in 37 of 50 fractures (74%). There was no statistically significant difference among the examined groups ($p > 0.05$).

In relation to posterolateral comminution, implant dynamics, meaning a migration of the lag screw(s) in the femoral neck or lateralization of the lag screw(s) due to fracture collapse, were observed more frequent in patients treated by surgical technique with multiple cancellous screws thickness of 6.3 / 7.5 mm and was greater than or equal to 10 mm which was statistically significantly ($\chi^2 = 6.474$, $p < 0.001$). Also, the union time was significantly shorter in SAF group (15.02 ± 1.44) compared to patients in CCS group (19.81 ± 2.94) with posterolateral fracture comminution ($\chi^2 = 7.048$, $p < 0.001$) (Table 3).

Comparing the fracture healing rate time with the degree of dynamization of implants in both groups of patients with posterolateral comminution, we came to the result that dynamization of implants significantly positively correlated with the fracture healing time in both examined groups, respectively (SAF: $r = 0.324$, $p = 0.025$; CCS: $r = 0.572$, $p = 0.001$) (Figure 4 and 5).

After one year of follow-up, HHS values (SAF: 89.7 ± 8.4 ; CCS: 82.2 ± 14.3) were similar, with no statistically significant difference ($\chi^2 = 2.44$, $p = 0.487$) (Figure 6).

Reoperation was performed in 5 patients (10.00%) of SAF group and 8 patients (16.00%) in CCS group of patients. It was found that there was no statistically significant difference in the incidence of reoperation rate between the tested method ($\chi^2 = 0.500$, $p = 0.696$).

Of the total number of patients operated by dual SAF implants, in five patients were performed reoperation procedures (two nonunions, one varus collapse and two healed fracture with advanced stage of femoral head necrosis - III and IV grade Ficat-Arlet classification). Because of the developing of the osteoarthritis of injured hip, total hip replacement was carried out in all cases.

DISCUSSION

So far, there are not many studies that looking at double screw femoral neck fixations [11]. Mostly, the authors compared the rates of treatment complications between fixed angular plate and three screw fixation methods, emphasizing significantly higher prevalence in blood loss and duration of operation in the group of patients treated with a fixed angular plates [12,13]. Our data suggest that the use of the CCS was associated with a approximately 14 min longer surgery which was significantly shorter in the SAF group of patients (52.89 min vs. 39.17 min, $p < 0.0001$, $p = 0.62$, unpaired t-test).

Screw loosening, fracture displacement and some other complications may often occur with regards to the internal fixation of femoral neck fractures, which in turn increases the rates of nonunion and femoral head necrosis [14]. Furthermore, it is generally known that the compressive forces have a positive impact on fracture healing, but it is unclear what the degree of dynamic compression is needed to promote healing the fracture, in order to prevent the prevalence of the shear forces which are the main cause of mechanical failure of fixation [15, 16]. During healing of femoral neck fracture, both bone resorption and shear forces of the fracture site can result in secondary sliding and displacement, even though the fracture was reduced in anatomic reduction quality, which tend to cause femoral neck shortening resulted in poorer functional outcome scores compared to patients who healed in an anatomic position[17]. Our study shows that dynamization of implants significantly positively correlated with the fracture healing time in both examined groups, respectively (SAF: $r = 0.324$, $p = 0.025$; CCS: $r = 0.572$, $p = 0.001$) indicating that fracture union rate was significantly shorter in group of patients treated with SAF method of fixation - averaged 15 weeks ($15,02 \pm 1,44$) on related to CCS group of patient which was averaged 19 weeks

(19,81±2,94) ($X^2/z = 7.048$, $p < 0.001$). It follows that SAF fixation improves rotational control of fracture fixation representing technically less demanding procedure.

Secondary sliding of implants (dynamization), which leads to resorption of fragments and shortening of the femoral neck, lasts until the end of the third month postoperatively, as part of normal bone consolidation. In cases of poor quality fracture reduction and severe osteoporosis this event can cause uncontrolled excessive shortening of the femoral neck, which further leads to higher possibilities of nonunion and fixation failure after femoral neck fractures [18]. Data from the literature suggest that there is a high incidence of the unacceptable collapse of the femoral neck (≥ 10 mm), approximately 30%, after fixation displaced and undisplaced femoral neck fracture with posterolateral comminution with three cancellous screws, the thickness of 6.5 or 7.3 mm [19]. In our study average dynamization of the implant in SAF group was 5 mm, while in a CCS group it was 17 mm, which was a statistically significant difference ($p < 0.001$). Despite the overall better value of HHS score for patients who had undergone SAF surgery (SAF: 89.7 ± 8.4 ; CCS: 82.2 ± 14.3), we found no statistically significant difference in functional recovery after one follow-up among the tested groups ($\chi^2 = 2.44$, $p = 0.487$). Considering the study's average revision rate among the studied groups (SAF = 6% vs. CCS=8%) no significant difference between the two groups could be seen.

According to previous findings, it has been well known that the disruption of posterior wall of the femoral neck fractures is a major cause of excessive shortening of the femoral neck during the healing phase, and that adversely affects fracture healing, functional outcome and the occurrence of reoperation rate [20]. To ensure stable fixation and healing of the femoral neck fractures, it is necessary to secure three point of support which need to be adjusted to the biomechanical characteristics of the implant: the subchondral bone head of the femur for rotational stability (1st point of fixation), Adam's arch and femoral calcar of the neck of the femur (2nd point of fixation) and support of lateral femoral cortex (3rd point of fixation) [21,22].

If Adam's arch of the caudal fragments remains intact (as it happens in the majority of femoral neck fractures) use of thick, rigid plate, such as dynamic compression plate, is not required, and placement of free cannulated screws are enough for secure fracture fixation. Placed in parallel position, free cancellous screws gives enough support to the femoral calcar

and Adam's arch [23,24]. This approach also produce less trauma to the soft tissues and require a shorter duration of surgery. In our series intraoperative blood loss and average fluoroscopy time were similar in both groups, with no significant difference ($p = 0,75$; $p = 0,62$) which supports this claim.

But, in the cases when Adam's arch as the support of the second point of fixation is missing and can't support the implant (Pauwels type III of femoral neck fractures, basocervical femoral neck fractures, comminutive femoral neck fractures), double lever becomes a single, and large load suffer lateral cortex of the femur as a third point of support of internal fixation [25]. In these situations, additional reinforcement with an appropriate implant is required, in order to achieve resistance to the shear force inherent in these vertical fractures. Recently, the use of a medial buttress plate on the medial side of the femoral neck has been proposed by some authors, with satisfactory initial results. However, it requires a more extensive surgical dissection and care must be taken not to damage the femoral head blood supply [26,27]. Self-tapping Antirotational Fixation (SAF) in most cases in our study was performed after closed reduction (90%) as a less surgically demanding procedure, where even after open fracture reduction (10%) adequate dynamic compression of the fracture site was provided without additional damaging the blood supply to the femoral head (LFCA and MFCA) (Figure 7). In order to achieve better angular stability and dynamic compression of the unstable Pauwels III fracture, recently, AO foundation authors introduced new implant called Femoral Neck System (FNS) (DePuy Synthes, Zuchwil, Switzerland), to improve the biomechanical performance of fracture fixation. They have biomechanically proven that implant is superior versus fixations with 3 parallel cannulated screws and comparable to both dynamic hip screw (DHS) with antirotation screw and DHS with blade in terms of sustainability of the restored neck length for unstable Pauwels III fractures [28].

One of the proofs overloading the third point of internal fixation of the femoral neck fractures is a thickening of the lateral cortex at the site around the distal screw, which was clearly visible on x-rays several weeks after dual SAF screw fixation. The pain was present until the "biological plate" didn't finish its formation and provide solid support to the screw (Figure 8).

This phenomenon can be explained by the presence of micro-movements of the screw due to the load, causing osteogenesis followed by formation at first irritative callus, and then

supportive periosteal callus around the distal screw on the lateral femoral cortex. This example shows that the lateral cortex could not always respond to the high demands that are placed in front of the third fixation point and that even in the cases of perfect fracture reduction and stabilization, micro-movements occurred. To avoid loss of reduction or excessive shortening of the femoral neck after internal fixation with free cannulated screws, it is necessary to strengthen the lateral cortex, especially in the case of osteoporotic patients [29].

The present retrospective study has certain limitations, that must be acknowledged. First, it is a preliminary report with a small number of cases. Second, we found a small number of AVN cases in SAF group, which may be due to the short follow-up period. But it has certain character, which is reflected in the fact that the data analyzed here cover particular type of injury, where a large number of patients suffered unstable femoral neck fractures, almost equally distributed (SAF=28% vs. CCS=26% according to Garden type, SAF=38% vs. CCS=42% according to Pauwel's type) in both studied groups.

CONCLUSION

Our data shows that the double screw Self-tapping Antirotational Fixation (SAF) prevents the excessive collapse of the femoral neck fracture, respecting the principles of three-point fixation, acting as a load sharing device. Likewise, with significantly shorter duration of surgery, SAF provides optimal conditions for the healing of the comminuted fracture without further shortening the length of the femoral neck and functional damage to the hip abductor lever in properly selected patients. There is also a trend supporting the preferential use of the SAF over the CCS in terms of complication rates but lacks statistical significance. Nevertheless, more clinical prospective randomized trials should be done to evaluate the effectiveness of this implant.

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The study was approved by the local Medical Research Ethics Committee (ref. no. 12-2466-12, approval date 9 March 2015) and carried out according to the declaration of Helsinki.

Conflict of interest: The author Milorad B. Mitković at the moment of writing the paper has an agreement on temporary assignment to the use of the patent. Other authors declare no conflict of interest.

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Table 1. Patient data among the study groups

Patient data		SAF (n = 50)	CCS (n = 50)	P
Age (years) mean \pm SD (min-max)		58.06 \pm 10.35 (27-79)	51.86 \pm 16.52 (16-80)	0.027
Sex (%F, %M)		40%F, 60%M	46%F, 54%M	>0.05
Garden class	I	14	10	>0.05
	II	22	27	>0.05
	III	11	10	>0.05
	IV	3	3	>0.05
Pauwels class	I	31	29	>0.05
	II	17	18	>0.05
	III	2	3	>0.05
CRIF n (%)		45 (90%)	37 (74%)	0.038

SAF – self-tapping antirotational fixation; CCS – cannulated cancellous screws; CRIF – closed reduction and internal fixation

Table 2. Reduction quality assessment among the study groups

Assessment of reduction	Total n (%)	SAF n (%)	CCS n (%)	χ^2	p
acceptable	39 (39%)	20 (40%)	19 (38%)	1.428	0.490
anatomical	54 (54%)	28 (56%)	26 (52%)		
poor	7 (7%)	2 (4%)	5 (10%)		

SAF – self-tapping antirotational fixation; CCS – cannulated cancellous screws

Paper accepted

Table 3. Posterolateral comminution, union time and dynamization of implant

Characteristics	SAF	CCS	χ^2/z^*	p
Posterolateral comminution n (%)	43 (86%)	43 (86%)		1.000
Union time (weeks) mean \pm SD (min-max)	15.02 \pm 1.44 (10–22)	19.81 \pm 2.94 (12–26)	7.048*	< 0.001
Dynamization of implant (mm) mean \pm SD (min-max)	3.33 \pm 1.96 (0–10)	13.18 \pm 6.21 (2–24)	6.474*	< 0.001

SAF – self-tapping antirotational fixation; CCS – cannulated cancellous screws

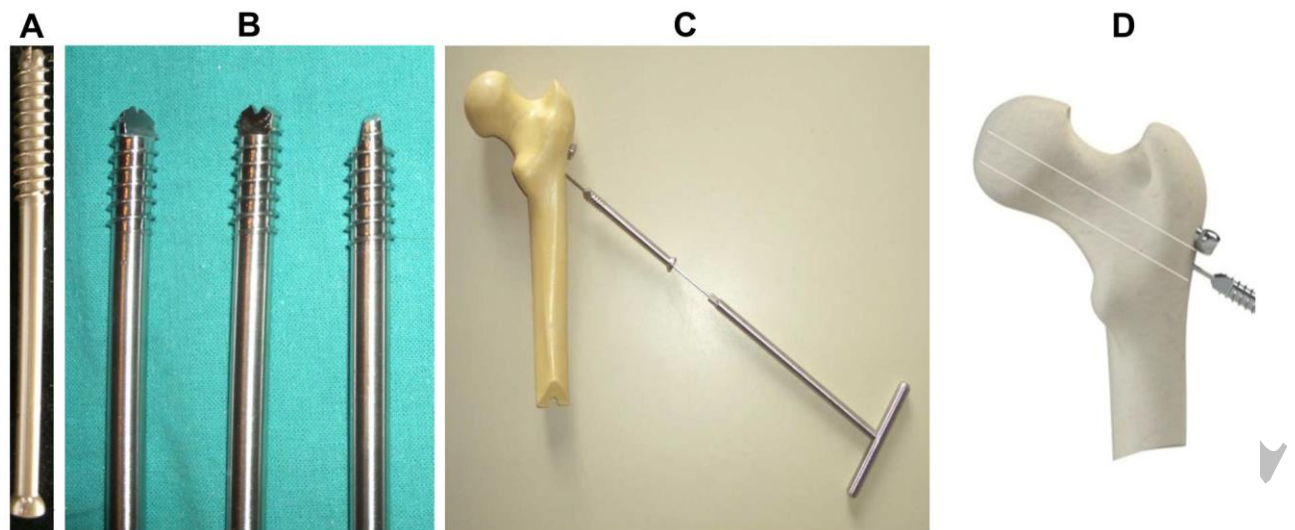


Figure 1. Standard AO 6.5 mm cannulated cancellous screw (A); self-tapping cannulated self-tapping antirotational fixation screws and position of the implant in femoral neck (B, C, D)

Paper accepted

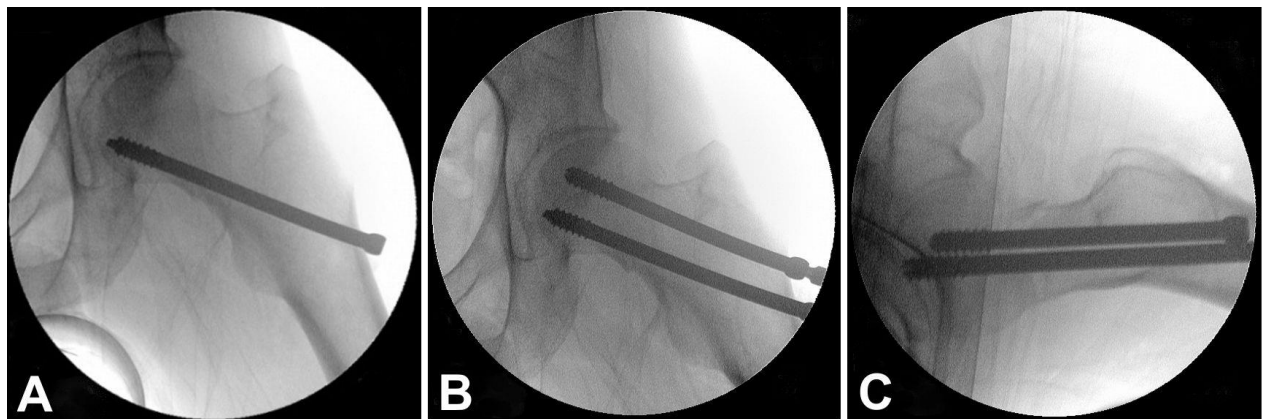


Figure 2. Plane radiographs to verify correct placement of self-tapping antirotation screws femoral neck fixation (A – distal screw placement, B – proximal screw placement, C– profile parallel placement)

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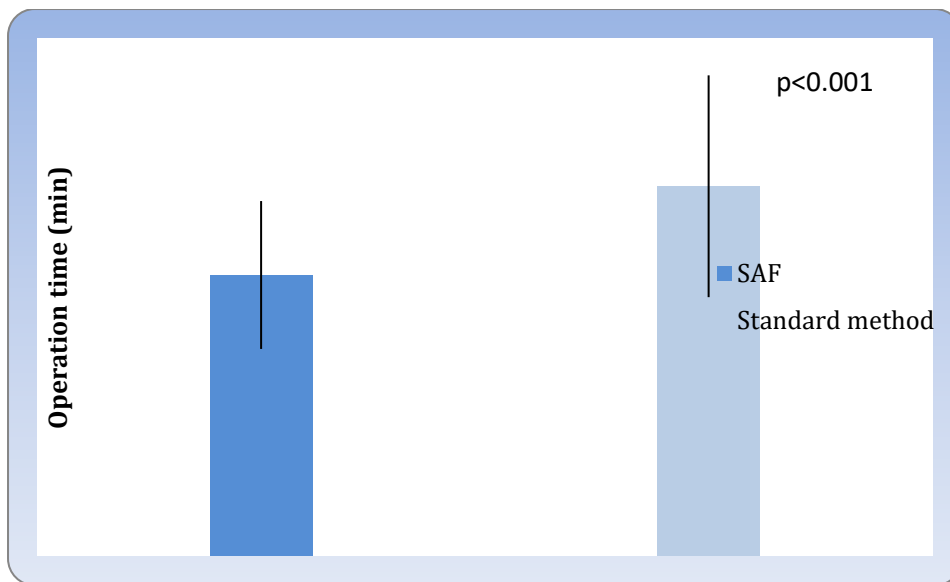


Figure 3. Operating time among studies groups

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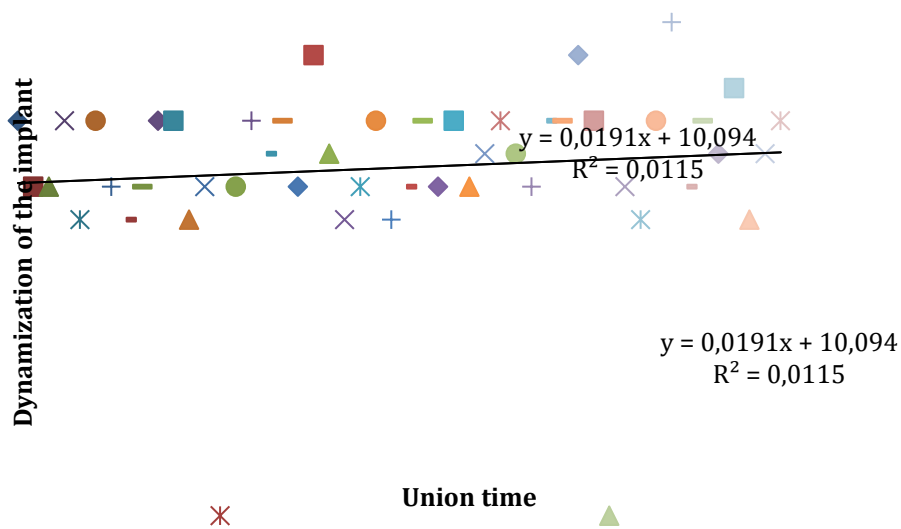


Figure 4. Relationship between implant dynamics and fracture healing time in patients undergoing cannulated cancellous screws fixation

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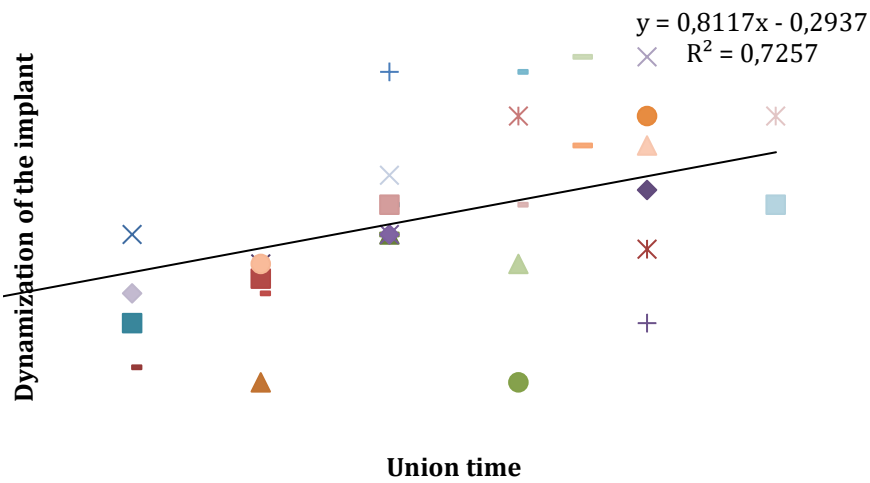


Figure 5. Relationship between implant dynamics and fracture healing time in patients undergoing self-tapping antirotational fixation

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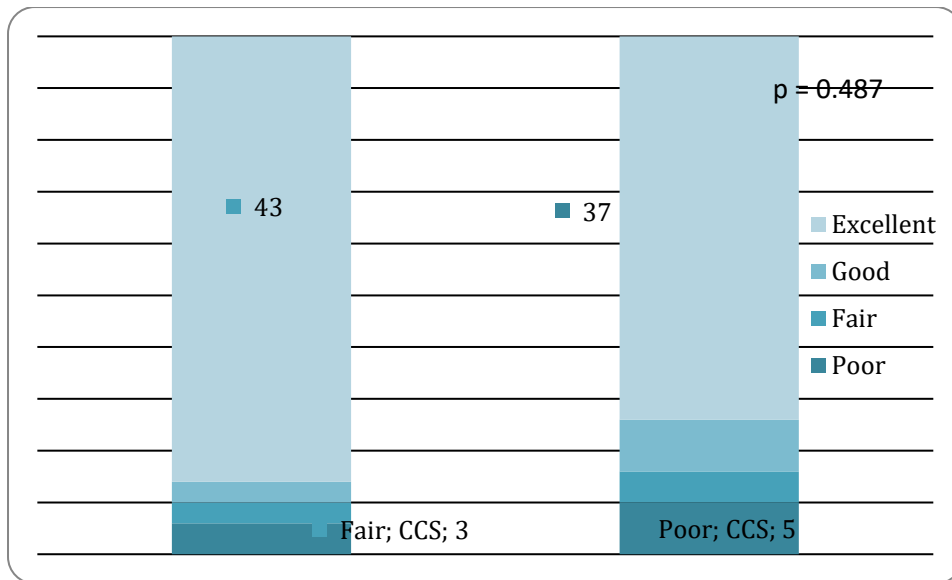


Figure 6. Assessments of complete functional recovery obtained by Harris's hip score

Paper accepted

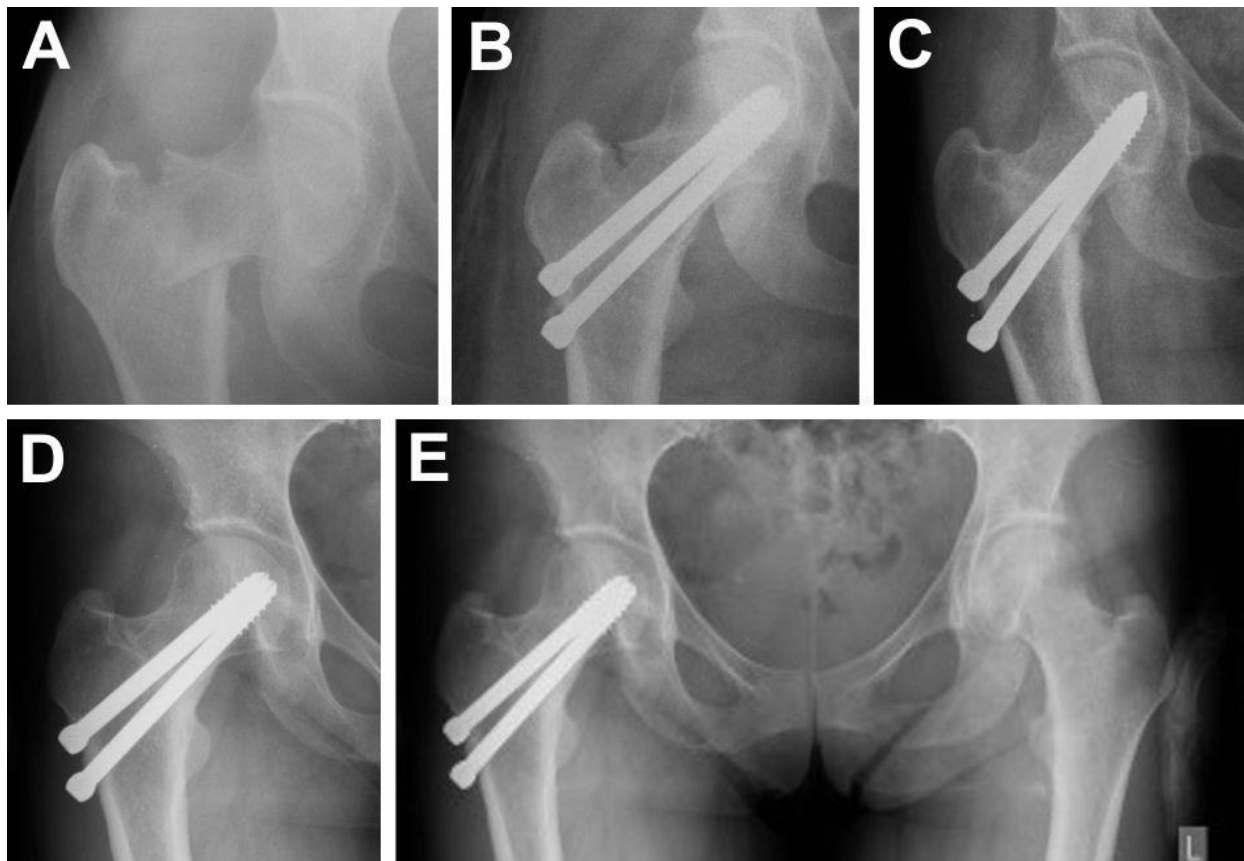


Figure 7. Forty-three-year-old female patient with unstable vertical (Pauwels III) intra-capsular femoral neck fractures, when Adam's arch is missing and lateral cortex suffers the greatest load, in our series of patients treated with two self-tapping antirotation screws – serial follow up X-ray (A – initial, B – 12 weeks postoperative, C – 6 months, D – 12 months, E – 24 months postoperative)

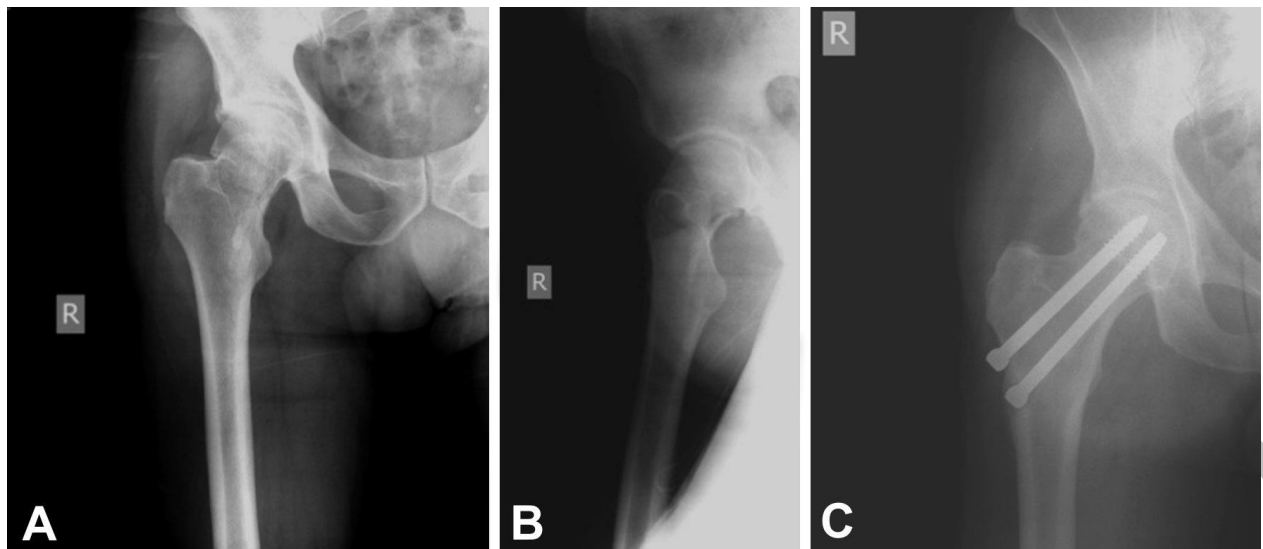


Figure 8. Effect of “biological plate”: AP view of femoral neck fractures with posterior wall comminution in 63-year-old male patient (A); profile view indicated disrupted posterior wall of femoral neck fractures (B); six months postoperative X-ray show significant thickening of the lateral cortex around the distal screw with fracture healing (C)