

Biplane double-supported screw fixation (F-technique): a method of screw fixation at osteoporotic fractures of the femoral neck

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Abstract The present work introduces a method of screw fixation of femoral neck fractures in the presence of osteoporosis, according to an original concept of the establishment of two supporting points for the implants and their biplane positioning in the femoral neck and head. The provision of two steady supporting points for the implants and the highly increased (obtuse) angle at which they are positioned allow the body weight to be transferred successfully from the head fragment onto the diaphysis, thanks to the strength of the screws, with the patient's bone quality being of least importance. The position of the screws allows them to slide under stress with a minimal risk of displacement. The method was developed in search of a solution for those patients for whom primary arthroplasty is contraindicated. The method has been analysed in relation to biomechanics and statics. For the first time, a new function is applied to a screw fixation—the implant is presented as a *simple beam with an overhanging end*.

Keywords Femoral neck fixation · Osteoporotic fractures · Hip · BDSF

Introduction

The present work introduces a method of screw fixation of femoral neck fractures in the presence of osteoporosis, according to an original concept of the establishment of two supporting points for the implants and their biplane positioning in the femoral neck and head. The console-like

proximal femur demands the fixation screws have to support the weight-bearing head fragment, acting like a beam with an overhanging end, which must have two points of support in the distal fragment. That is the principle which the concept of the Biplane double-supported screw fixation (BDSF) method is based on. What is original about this method is that the three screws are laid in two planes, which makes it possible for the entry points of two of the implants to be placed much more distally, in the solid cortex of the proximal diaphysis, and also to lean onto the femoral neck distal cortex. Thus, we establish two supporting points. The position achieved by the distal as well as the middle screw, in view of *statics*, turns them into a *simple beam with an overhanging end, loaded with a vertical force*. This beam with an overhanging end successfully supports the head fragment, bearing the body weight and transferring it to the diaphysis.

Operative technique

Indications: Fractures of the Garden types from I to IV.

Implants: 7.3-mm self-tapping cannulated screws.

Reduction: a mild traction, internal rotation and a light abduction of the limb are applied. Solely anatomical reduction is acceptable.

Approach: A straight lateral incision, starting at the level of the lower end of the greater trochanter, with a distal length of 6–10 cm. A stripping of the periosteum of the lateral diaphysis at 6–7 cm is performed.

Placement of the implants: With the BDSF method, the three cannulated screws are placed in the frontal plane at a highly increased angle. Both the distal and the middle

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screws touch on the curve of the distal femoral neck cortex tangentially. At internal rotation of the leg, in A–P view, the projection of the distal screw crosses the projections of the other two screws, thus forming the letter F (F-technique). Via the concept of *biplane positioning*, developed by the BDSF, the three screws are placed in two vertical oblique planes (in lateral view). The two planes diverge towards each other in the direction of the femoral head and are oblique towards the frontal plane. The distal screw is laid in the dorsal oblique plane. The middle and the proximal screws are placed in the ventral oblique plane (Fig. 1).

Firstly, we lay the guiding wire for the distal cannulated screw. Its tip is placed 5–7 cm distally from the basis of the trochanter in the anterior one-third of the surface of the stripped-off diaphysis. It is directed proximally at an angle of 150–165° towards the diaphyseal axis, with inclination from anteriorly–distally to posteriorly–proximally, so that after it touches on the curve of the distal femoral neck cortex tangentially, the wire goes into the dorsal half of the femoral head.

The middle guiding wire is placed second. The entry point is at 2–4 cm proximally from the entry point of the distal wire, in the dorsal one-third of the stripped-off surface of the diaphysis. This wire is placed at an angle of 135–140° towards the diaphyseal axis and inclined from posteriorly–distally to anteriorly–proximally, so that after it touches on the curve of the distal femoral neck cortex tangentially, the wire goes into the front one-third of the femoral head. In the frontal plane (A–P view), the tip of this guiding wire goes into the distal one-third of the femoral head.

Last to be laid is the proximal guiding wire, with its entry point at 1–2 cm proximally from the entry point of

the middle wire, in the dorsal one-third of the stripped off diaphysis, close to the beginning of the trochanter. Placed parallel to the middle wire, the proximal wire goes into the front one-third and into the proximal one-third of the femoral head.

The guiding wire easily changes its initial direction when passing through the thick diaphyseal cortex, and therefore, its tip is guided into the desired direction by the operator's free hand with the help of a cannulated instrument. Next, we drill and place the screws one by one. Before placing the middle and distal screws, we overdrill their holes in the lateral cortex by using a 7.0 mm cannulated reamer.

The middle and the proximal screws are placed first because they are perpendicular to the fracture surface. Next, we release the foot traction, and a several-time impaction of the fracture with an additional tightening up of the screws follows. Finally, the distal screw is placed.

Radiographic time: from 0.2 to 0.3 min.

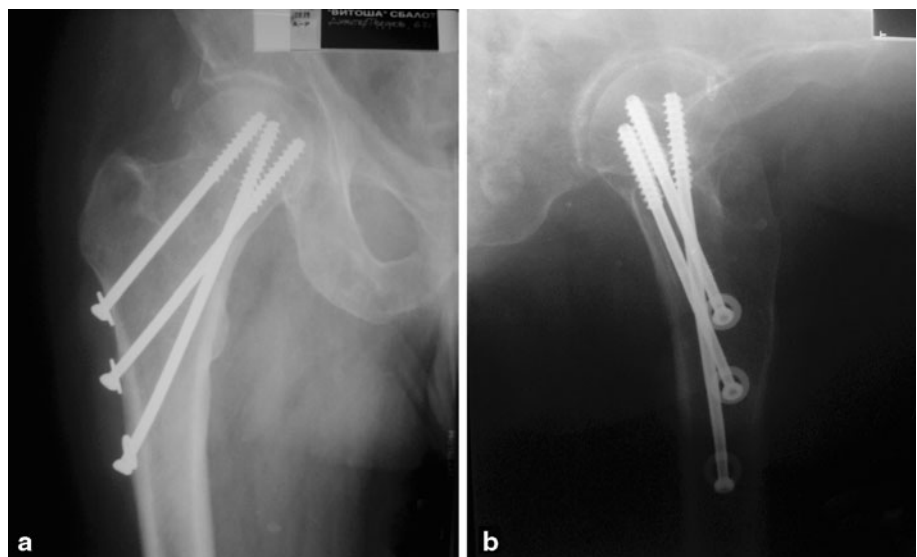
Mean operative time: 39 min (30–45 min).

Postoperative period: Limited weight bearing for 4–6 months by using two crutches.

Biomechanical basis of the method of BDSF (F-technique)

What is innovative about this method is that the three screws are laid in two planes, which makes it possible for the entry points of two of the implants to be placed much more distally, in the solid cortex of the proximal diaphysis, and also to lean onto the femoral neck distal cortex. Thus, we establish two supporting points. The solid distal cortex

Fig. 1 Radiography. **a** A–P view; **b** Lateral view



of the femoral neck acts as a medial supporting point for the screws, which works under pressure—supporting point A. The entry points of two of the screws (the distal and the middle ones) in the thick cortex of the diaphysis ensure a second solid supporting point for the screws—a lateral one, which works under tension (pressure in proximal direction)—supporting point B. The position of the distal screw as well as the middle screw thus achieved by the method, in terms of *statics*, turns them into a simple beam with an overhanging end, loaded with a vertical force. This beam with an overhanging end successfully supports the head fragment bearing the body weight and transferring it to the diaphysis. Furthermore, due to the biplane placement, enough space for a third screw is provided, unlike the classical authors' models, where just one or a maximum of two implants are placed at an obtuse angle [3, 4]. Another advantage of the method is that due to the increase in the distance between the two supporting points, the weight borne by the bone is reduced (*see the static analysis*). An advantage of the BDSF method is that the entry points of the screws are positioned wide apart from each other, which ensures that when weight bearing, the tensile forces spread over a greater surface of the lateral cortex and thus the risk of its fracturing decreases significantly. An advantage with the BDSF is also that the screw, placed at a highly increased angle, works in a direction close to the direction of the loading force, which guarantees better results for the screw in its role of a beam because of the influence of its sagging decreases.

Static analysis

With the conventional methods of femoral neck fixation by three cancellous screws, placed parallel to each other and parallel to the femoral neck axis, the entry points of the three screws are placed at the thin cortex of the greater trochanter or close to it. The screws are often located in the soft cancellous bone near the axis of the femoral neck, without any cortical support. With conventional methods, due to the lack of two solid supporting points, the implant works statically like a *beam on an elastic foundation*. The elastic foundation is realized by the cancellous bone.

Unlike the conventional methods, with the BDSF method, the implant is additionally supported at points A and B of the cortex. The interaction between the implant and the cancellous bone is neglected because of the comparatively small stiffness of the cancellous bone. In such a way, with sufficient practical accuracy, with BDSF method, the static model is assumed to be a *simple beam with an overhanging end* (Fig. 2). This beam is supported at points A and B only.

Using the well-known equilibrium equations for a beam, we obtain the forces acting on the cortex at supporting points A and B.

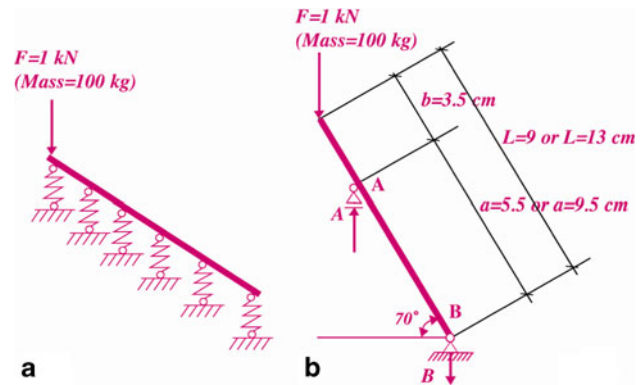


Fig. 2 Static models of the implant. **a** A beam on elastic foundation; **b** A simple beam with an overhanging end. F load, L = length of beam; a distance between points A and B

The load acting at point A is pressure in a distal direction and denoted as $A = \frac{FL}{a}$;

The load acting at point B is pressure in a proximal direction and denoted as $B = A - F$.

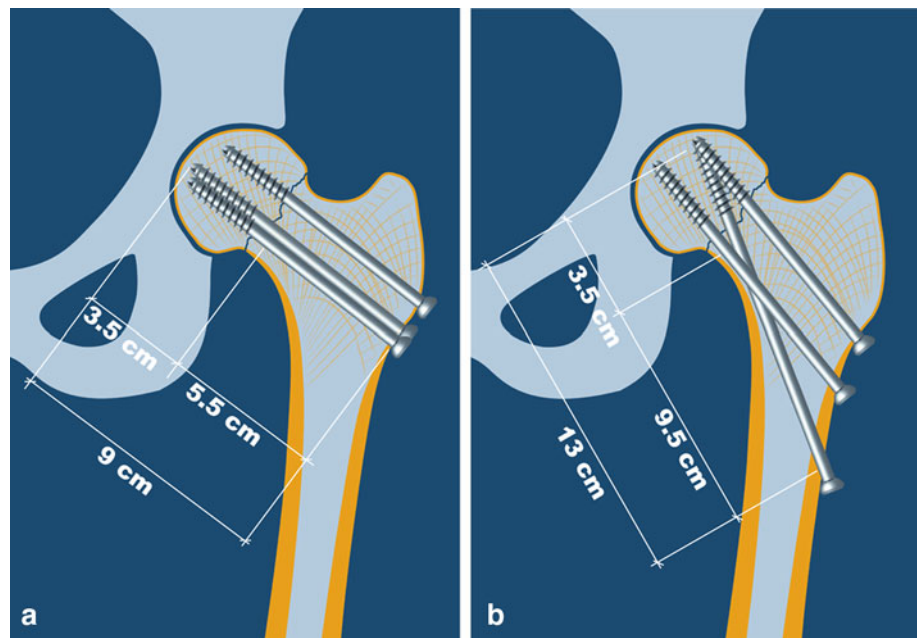
With the BDSF method, due to the increase in the distance between the two supporting points, the weight borne by the bone is reduced. If we look at two cases of equal vertical weight but different distances between the supporting points, we will see that the greater the distance, the smaller the weight at each of the two supporting points. The average anatomical distance from the tip of the screw to the curve of the distal femoral neck cortex (point A) is 3.5 cm (Fig. 3).

With conventional methods (case 1.), the average distance from point A to the entry point of the screws in the lateral cortex (point B) is 5.5 cm ($a = 5.5$ cm). In order for a comparison with the BDSF to be made, when given a body weight of 100 kg, with conventional methods, the load acting on the curve of the distal cortex of the neck (if the screws lean on this support at all) is estimated at $A = 1.63$ kN (163.63 kg). The load on the fragile lateral cortex (point B) is estimated at: $B = 0.63$ kN (63.63 kg), directed in the opposite direction (proximally).

With the BDSF method (case 2.), when increasing the angle of the implant towards the diaphysis, the distance between points A and B increases by 4 cm to reach 9.5 cm ($a = 9.5$ cm). Because of this, the load on the cortex decreases significantly. Given the same body weight of 100 kg, the load acting on the medial supporting point is $A = 1.36$ kN (136.84 kg) or 16.38% less than conventional methods, and on the lateral supporting point, the load is $B = 0.36$ kN (36.84 kg) or 42.11% less than conventional methods. The distal screw normally applied with the BDSF method has a length of 13 cm.

The stressed state of the lateral cortex round point B is complex. It is subject to normal compressive stress in a proximal direction, as well as to horizontal tensile stress. In the lower part of the cortex, the stress is mainly tensile.

Fig. 3 Fixation of the femoral neck (*scheme*): **a** Conventional method; **b** The BDSF method



Results

From a series of 178 operated patients, 88 were studied. Of the 88 studied patients, 27 (30.68%) are men and 61 (69.31%) women; the average age is 76.9 (with the youngest patient aged 38 and the oldest aged 99). Grouping patients by age: 18 patients (20.45%) are under 69; 27 patients (30.68%) are aged 70–79; 37 patients (42.04%) are aged 80–89; 5 patients (5.68%) are aged 90–95; 1 patient (1.13%) is aged 95–100. More than one accompanying diseases, which influence the results of Harris hip score, were found in 21 patients (23.86%). The average follow-up period is 8.06 months.

The fractures have been classified by the Garden classification as follows:

Garden type I: 3 (3.41%); Garden type II: 1 (1.14%); Garden type III: 9 (10.23%); Garden type IV: 75 (85.02%).

Results: From the studied 88 patients, fracture union was registered in 87 patients (98.86%) and failure in 1 patient (1.13%).

Assessment according to the Harris hip score (modified): poor results in 10 patients (11.36%). Fair results in 20 patients (22.72%). Good results in 21 patients (23.86%). Excellent results in 37 patients (42.04%).

The average Harris hip score is 84.26 points [6].

Discussion

Today's popular conventional methods of femoral neck fixation by three cancellous screws, placed parallel to each

other and parallel to the femoral neck axis, are associated with poor results in 20–42% [1, 2, 5, 9, 12, 13]. The high failure rate of conventional screw fixation methods can be explained by the presence of a number of biomechanical imperfections. (1) Lack of stability of the construction regarding varus stress. The femoral neck fracture is subject to powerful shearing forces due to the angular, spiral-like architecture of the proximal femur. In order to provide resistance to the shearing forces, in the presence of osteoporosis, the screws must be solidly fixed in the distal fragment in at least two points. This requirement is not met with conventional screw fixation methods, in which the entry points of the three screws are placed at the thin cortex of the greater trochanter or close to it. The screws are often located in the soft cancellous bone near the axis of the femoral neck, without any cortical support. Even if the distal screws (one or two) are placed close to the distal cortex of the femoral neck, they are deprived of a second solid point of support. A second point of support for them is the thin and fragile lateral cortex of the greater trochanter—their entry point. Such a construction can rely solely on the interfragmental compression, created by the tightening of the screws intraoperatively, but the achieving of compression depends on the solidity of the cancellous bone. This leads to high failure rate in the cases of osteoporosis. (2) Lack of sliding phenomenon. (3) Inability to move the entry point of the screws distally into the solid diaphyseal cortex while simultaneously positioning three parallel screws. In 1961, Garden [4], like others before, further developed the concept that the implants must be placed more vertically, similar to the direction of the medial compression lamellae of the internal trabecular

system, in order for resistance to the shearing forces to be provided. However, when developing this concept, classical authors used only one implant (a nail). In this way, the implant successfully provides resistance to the shearing forces but does not create compression among the fragments, because it is not a screw and is also not able to ensure reliable rotational stability of the head fragment, because the implant is just one [7, 10, 14].

The anatomy of the proximal femur does not allow three screws to be placed simultaneously, being parallel to each other; laying near the cortex in the periphery of the neck and at the same time having their entry point positioned distally, in the solid cortex of the diaphysis, so that the fragile lateral metaphyseal cortex is avoided. With the conventional methods of positioning of three parallel screws, if movement of the screw entry point distally is attempted, the screws will be placed at a very obtuse angle towards the diaphysis and obliquely to the femoral neck. By increasing the angle of penetration, the surface of the femoral neck cross section decreases geometrically, and practically, the placement of more than one or two screws is difficult to accomplish. Furthermore, a two-screw fixation does not provide reliable stability in all planes [14].

Both problems are resolved by the BDSF method through the concept of *biplane positioning* of three screws at an obtuse angle. The provision of two steady supporting points for the implants and the obtuse angle at which they are positioned allow the body weight to be transferred successfully from the head fragment onto the diaphysis, thanks to the strength of the screws, with the patient's bone quality being of least importance. The position of the screws allows them to slide under stress at a minimal risk of displacement. The achieved results with the BDSF method in terms of fracture consolidation are far more successful than the results with conventional fixation methods. The BDSF method ensures reliable fixation, early rehabilitation and excellent long-term outcomes, even in non-cooperative patients. BDSF is mainly addressed to patients, who have contraindications for arthroplasty, as well as for conventional screw fixation.

Conflict of interest No benefits in any form have been or will be received from a commercial party related directly or indirectly to the subject of this manuscript.

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