THE FEMORAL NECK FRACTURE:
A BIOMECHANICAL STUDY OF TWO INTERNAL FIXATION
TECHNIQUES

Branko Ristić, Miodrag Bogosavljević
1Centre of Orthopaedic Surgery and Traumatology, CHC Kragujevac, 2Department of Orthopaedic Surgery, MG Pažarevac

PRELOM VRATA BUTNE KOSTI:
BIOMEHANIČKA STUDIJA DVE TEHNIKE UNUTRAŠNJE
FIKSACIJE

Branko Ristić, Miodrag Bogosavljević
1Centar za ortopediju i traumatologiju, KBC Kragujevac, 2Ortopedsko odeljenje, MG Pažarevac

SAŽETAK
Optimalni metod interne fiksacije preloma vrata butne kosti je još uvek predmet rasprava. Danas se za sintezu ovih preloma najčešće koriste višestruki spongiosi zavrtvi i dinamički ugašeni implantati. Cilj ovog rada je bio da se uporedite biomehanička svojstva dve tehnike unutrašnje fiksacije (3 spongiosa paralelna zavrtnja, odnosno novi dinamički ugašeni implant D urgent YU) na kadaveričnim modelima preloma vrata butne kosti. METOD: Čvrsta fiksacija preloma vrata butne kosti sa novim dinamičkim implantatom i 3 spongiosa paralelna zavrtnja je uspoređivana na pet pari kadaveričnih femura. Nije postojala statistički značajna razlika u čvrstini intaktnih femura, košnjom gustini i obješenim kontekstan između ispitivanih parova. Osteotomijski je širša izravno na uzdužnu osnovu vrata butne kosti. Preparati su podvrgnuti sliči od 1501N (fiziološko opterećenje) i određena je zahteva čvrstine srednjih preparata u odnosu na intaktnu čvrstinu femura. REZULTATI: Femuri fiksirani sa novim dinamičkim ugašenim implantatom D urgent YU ostvareno su statistički značajno višu čvrstinu konstrukciju u odnosu na konvencionalnu fiksaciju koji su fiksirani sa 3 spongiosa paralelna zavrtnja (p<0.05). ZAKLJUČAK: Rezultati pokazuju da fiksacija preloma vrata butne kosti sa novim D urgent YU implantom ostvareno je statistički značajno bolju čvrstost preloma u odnosu na metodu fiksacije sa 3 spongiosa paralelna zavrtnja, što u kliničkoj praksi može imeti značajan uticaj na procese zrstenja i osvaljevanje nezdrave glaive femura. Ključne reči: prelom vrata butne kosti, unutrašnja fiksacija, čvrstost fiksacije, biomehaničko testiranje

INTRODUCTION
Stability of osteosynthesis in fracture of femoral neck in the early phases of patient’s recovery may have a crucial influence on healing processes and revascularization of femoral head.

The most important factor in healing of the femoral neck fracture is directly affected by surgeon achievement of stable fixation. The importance of the stability in the healing of the fracture can be seen through the fact that the fractures without dislocation, when there is a good contact between fracture surfaces are almost always healing (1-4). The relation between bad preoperative stability and early loss of stable osteosynthesis together with nonunion was described by many authors (1, 5-7). Rehnberg and Olerud (1989) have proved that (by using instrumented intraoperative measuring) the femoral neck fractures that have healed, have much bigger intraoperative stability than the fractures that haven’t healed (p<0.001) (8).

Stability of the fracture depends on the quality of the bone tissue (osteoporosis and comminution), quality of the reposition of the fracture, the implants’ design and the position of the fixation device on the femoral neck and the head (4, 9, 10).

Apart from different opinions (11), it is obvious that besides the knowledge and skills of the surgeon, the choice of the implants plays a crucial role in some cases where stability of the fracture is concerned, which proves that some of the implants provide better stability of the fracture in the inconvenient situations (inappropriate reposition, bad quality of the bone tissue, stressed comminution of the fracture)

The fixation by parallel screws and by dynamic angular implants these days represents the most used method for internal fixation of intracapsular fractures of the femoral neck.

A few years ago, in our country the new implant (DHS-YU) has been designed, that has positive attributes of today’s most used implants for osteosynthesis of the femoral neck fracture: parallel screws and dynamic angular implants.
The purpose of this study was to present in an objective manner some of the biomechanical characteristics of fixation of the femoral neck fracture with 3 cancellous parallel crews and a new angular implant (DHS-YU) and their influence on the stability of osteosynthesis of this fracture.

MATERIAL AND METHODS

For the purpose of this study out of five cadavers, proximal parts of the femur (head, neck, trochanteric area and 10 cm of the femur diaphysis beneath the small trochanter), have been taken. The average ages of donors were 62 years (three men and two women). Previously, donors have never suffered a known hip disorder, or had any of the malignant diseases, nor did they have a known metabolic disorder of bones (except osteoporosis). After the removal of all soft tissue structures, the cadaver was kept in formalin.

To assess if there are differences in bone structure between left and right femurs taken from the same cadaver before the experiment, the following researches have been done:
1. The measuring of primary anatomic characteristics of the sample and the thickness of the cortex;
2. The determination of Singh's index,
3. The comparison of relative density of the bone tissue by computerized tomography and computer analysis of X-rays
4. Static compression test – the measuring of the intact bone stiffness (N/mm).

Every sample has been visually tested and the basic anatomic parameters have been measured: the head diameter, the length and width of the neck, the diaphysis diameter 100 mm from the top of the big trochanter and at the same place the thickness of the femur's cortex (12). These parameters have been measured by AP x-rays (40 mAs, 80kV), that were made before the testing. In order to avoid the mistakes in quality, every couple of femurs has been graphed on the same X-ray.

Based on the achieved X-rays, three independent researchers have determined the Singh's index (13) and the average value of the achieved evaluations has been taken into a consideration.

Bone density of the proximal femur was determined from the CT scans by using standardized slices through the intertrochanteric region (14).

Also, initial mechanical testing of intact femurs has been done, by loading to 1500 N to determined stiffness and deflection (14-17) (table 1.).

Before the osteotomy, and in order to achieve anatomic reposition, the implants were placed in femur (three parallel cancellous screws or a dynamic angular implant DHS-YU). By using the method of a random sample, it has been determined which implant should be placed in the right, or which in to the left femur.

<table>
<thead>
<tr>
<th>Table 1.</th>
<th>Quality, structure and biomechanical properties of left and right cadaveric femurs.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Left</td>
</tr>
<tr>
<td>Stiffness (N/mm)</td>
<td>191.9 ± 49.7</td>
</tr>
<tr>
<td>Osteodensity</td>
<td>0.97 ± 0.06</td>
</tr>
<tr>
<td>Singh index</td>
<td>5.2 ± 0.26</td>
</tr>
<tr>
<td>Cortex thickness (mm)</td>
<td>7.21 ± 0.27</td>
</tr>
<tr>
<td>Head radius</td>
<td>52.46 ± 2.07</td>
</tr>
<tr>
<td>Neck length</td>
<td>36.60 ± 3.17</td>
</tr>
<tr>
<td>Neck width</td>
<td>28.34 ± 3.07</td>
</tr>
</tbody>
</table>

In all samples the following has been achieved:
• that the tops of the screws were placed in a subchondral zone of the femur's head
• that the threads were located medially from the planned osteotomy;
• that the distal screw lies next to the medial cortex of the neck, or in other words it has a medial calcar support (18-21).
• cancellous screws were placed in a triangular order (one screws distally and two proximally) (18, 22) and are parallely placed, with a maximum deviation of 5 degrees (23, 24). The parallelism of screws of the DHS-YU implants secures the design of the device.

Femoral neck osteotomy were created by cutting circumference of the cortical bone with a thin blade under the right angle on the axis of the femur's neck in the middle between the head's chondral and the intertrochanteric line (11, 16, 19, 21). Followed by anatomical reposition in previously created bearings screws were placed and a synthesis of the fracture has been done. (20, 25). After that, the biomechanical testing began.

Distal section of the specimen (the femur's diaphysis) has been sunk in to the bone cement (PMMA) in a steel cylinder whose diameter was 5 cm with the inclination of 15° femur's diaphysis related to the frontal plane (21, 22, 26).

The specimen was mounted on a testing machine (Device for measuring axial and radial clires of the spherical joints (M2); Fabrika automobilskikh delova FAD Gorjini Milanovac). The load has been applied over a plastic model of acetabulum (fig. 1.).

The specimen was exposed to a load of 1500 N, with applied speed of 10 mm/min. in order to determine the remaining stiffness of the specimen (related to the stiffness of the intact bone) expressed in N/mm.

The applied load was chosen on the bases of the force magnitudes measured in vivo by the author's studies that used implantation of instrumentalyzed prosthesis. The weight load of a human (70 kg) is matching the loads that the proximal femur bears while walking fast or climbing a small staircase (26, 27).

The statistical analysis has included the descriptive statistics and the calculation of the average values for every
specimen separately. Then the files were statically processed and analyzed by a computer program for statistical processing.

In the specimens fixed by DHS-YU under the load of 1500N the impact of the fracture surfaces occurs with migration of the screws through the plate's neck (fig. 4.). In one specimen there was a starting cut-off of the screw through the femur's head which was the main reason for the fixation's stability loss.

![Figure 1.](image1)  The testing machine (Device for measuring axial and radial clines of the spherical joints (M2), Fakultats automobilisht delove PAD Comiji Milianovac).

**RESULTS**

The average intact stiffness of the proximal femur was 2004 ± 685,1 N/mm, or 1910 ± 481 N/mm for the two observed specimen groups.

The femur's neck fracture's stiffness fixed by three parallel screws was 921,0 ± 598,7 N/mm, or 1136,8 ± 712,2 N/mm for the group of specimens fixed by DHS-YU.

The fixed fracture of the femor's neck measured in percentage relates to the intact stiffness of the proximal femur is 38.83% ± 14.22% for the group of specimens fixed by 3 parallel screws or 60.68% ± 24.13% for the group of specimens fixed by DHS-YU implant (fig. 2.) and there is statistically important difference between the groups (P < 0.05).

**DISCUSSION**

There is no standard definition for the phrase “stability of the femoral neck fracture”, although this terminology is often used in literature and clinical practice. The stiffness of a material of some constructions can be defined as a deformation resulting from the load. In the experiments in vitro a deformation of the fixed osteotomy or a fracture under the certain load can be measured and analyzed, which has also been done in this research also.

The results have proved that the fracture synthesis with a new dynamic implant achieves better stiffness in relation to the fixation of the fracture with 3 s cancellous screws under the physiological load of 1500N.

In a similar fashion, the biomechanical attributes of the implants were evaluated in a great number of studies (17-19, 28, 29). Mutual comparison of the results in these studies as well as the results in this study is very difficult because of the differences in methodology of testing and the expressing of the achieved results. However, it should be said that Springer at all (1991) (17) have found out that the synthesis of the fracture with 3 or 4 cancellous screws or the Knowles's nail have an average of 53.5% to 71.6% of the intact femur's stiffness with the load of 100kg (1000N). Hernefalk and Messner (1995) (29) have had similar results in a similar test with the load of 700N (table 2.).

Despite having a much higher force in this research (1500N, the load that the hip can bear during walking) than in the mentioned articles, the specimens that were fixed with the DHS-YU implant contain the high level of stiffness, while the kept stiffness of the preparations fixed with 3 free screws, falls below 40 percent of the intact femur's stiffness.
Table 2. Results obtained by Hermel and Menstrue (see ref. 29).

<table>
<thead>
<tr>
<th>Implant</th>
<th>remaining stiffness</th>
<th>intact stiffness</th>
</tr>
</thead>
<tbody>
<tr>
<td>von Behr</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>Hansson (LIH)</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Uppsala</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>Cancellous screw</td>
<td>0.5</td>
<td></td>
</tr>
<tr>
<td>Deyrolle</td>
<td>0.8</td>
<td></td>
</tr>
<tr>
<td>DHS</td>
<td>0.8</td>
<td></td>
</tr>
</tbody>
</table>

After the testing has been completed and after the analyses of the specimens and their X-rays, it can be concluded that the basic advantage of the DHS – YU implant in comparison to the 3 parallel screws is the presence of the lateral support (lateral cortical plate with neck). In the dynamical angular implant with the starting load the screws can freely glide through the implants neck; there is a subsidence of the head with the screws and apposition of the fractured surfaces. The lateral support of the implant makes the varus rotation of the head impossible (fig. 4.).

The second reason that secures the advantage of the dynamic fixation is the ability of implant telescopic (30). That way the progressive impact on the fracture is insured, its stability is growing and the best conditions for the healing are maintained. If there is a good parallelism between the free screws (up to 5 degrees) (21) telescopic effect can also be achieved (the railway effect). However, if it is not succeeded, the crossed skies effect is gained.

Osteosynthesis gradually gains characteristic of statically fixation and instead of progressive impaction of the fracture, under the load a tendency towards the separation of fractural fragment is present (30). Also, in case of established osteoporosis, as soon as a first load (stress) is applied convergence of proximal screws towards distal screw is present and telescopical effect of the fixation is lost (fig. 5.).

Figure 5. Convergence of proximal screws towards distal screw

The third reason that explains why the dynamical implant achieved much better stiffness of the fixation construction with three cancellous screws is the shortening of the moment arm distance which acts on the screws (31). Moment arm distance in the DHS-YU stretches from the top of the femoral head to the top of the medial neck’s end of the implant. Moment arm distance in free screws stretches from the top of the femoral head to the lateral cortex of the femora and is longer aprox. 2 cm. That increases the force on the screws and medial cortex under the same load which leads to the bigger decrease of the fixation stiffness.

CONCLUSION

The earlier studies proved that there was a positive correlation between the fracture healing and the postoperative stability of the fracture, so it can be concluded that by the use of the DHS-YU implants the frequency of the early loss of stability of synthesis and pseudoarthrosis in the intracapsular fractures treated by internal fixation can be radically lowered in relation to the synthesis with 3 parallel cancellous screws.

Cadaver studies allow us to compare some of the biomechanical characteristics of the implants with an accurate definition of the experimental conditions for the femoral neck fracture with a great dose of objectivity. However, it must be said, that because of being practically impossible to simulate the conditions in vivo, the results of the studies in the clinical practice should be critically applied, with observing some of the other factors that have an influence on successful treatment results.
REFERENCES


