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MATHEMATICAL MODELING IN THE PLANNING OF OSTEOSYNTHESIS IN TROCHANTERIC FRACTURES OF THE FEMUR

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Abstract. For this study, a total of 42 patients who underwent surgery for trochanteric fractures of the femur (A31-A1, A31-A2, A31-A3 AO, Muller's classification) and underwent surgery by modelling (modelled group, medical histories of patients (n=22 and non-modelled group n=18) were analyzed retrospectively and prospectively. Before surgery, modelled and non-modelled groups were compared by body mass index, time spent in surgery, and blood volume lost.

Key words: trochanteric fractures of the femur, mathematical modelling, retrospective method, prospective method, Electronic optical extender

INTRODUCTION

Fractures of the proximal part of the femur remain one of the urgent problems in the field of health care. According to Swedish scientists, fracture of the proximal part of the femur is associated with old age. Particularly, 97.8% of those with this type of fracture are 50 years of age or older, which highlights its prevalence among the elderly. In addition, the majority of these fractures, 77.2%, were 75 years of age and older, which indicates that the oldest age group has a higher risk of this type of fracture[1]. The high incidence of proximal femur fractures in adults may be due to several factors. As they age, their bone density decreases, making bones more prone to fractures, especially in the proximal femur. In addition, age-related changes in gait, balance, and muscle strength may increase the risk of falls, a common cause of proximal femur fractures in the elderly [9]. Another important point is that the disease is widespread among the elderly, it is related to osteoporosis, that is, it is related to physiological changes in old age [6].

Due to the unique anatomical and physiological characteristics of the proximal part of the femur, injuries of this area are considered a relatively complex type of injury not only in the elderly, but also among young people [7]. Currently, there are several methods for treating injuries of the proximal part of the thigh:

Cannula screws. Cannulated screws are usually used for stable or minimally displaced fractures. In this surgical practice, screws are mainly used for intracapsular bone fractures, and differ from other methods by the fact that screws are performed through a small incision [10].

The method of osteosynthesis with a bone plate is less invasive, reducing the time of surgery, as well as the time of recovery. Plates are one of the osteosynthesis methods with high efficiency compared to traditional plates in orthopedic surgery, especially in the treatment of bone and interosseous fractures, and are distinguished from other osteosynthesis methods by their stability and convenience [3].

Intramedullary nailing. Intramedullary stenting involves the insertion of a metal stent into the intramedullary canal of the femur. It is often used in bone fractures and in surgical operations stabilizing certain types of fractures of the sub-bone areas. This method provides excellent stability and enables heavy lifting earlier than other methods [7].

Arthroplasty, in some cases, it is advisable to perform femur arthroplasty in the case of fractures with fracture complexity and femur bone fragmentation, if there is arthrosis in the joint. In this case, the pelvis-femoral joint is restored by replacing the broken part of the femur with an artificial joint [4,8,2].

METHODOLOGY

In this research, in 2019-2022, in the Republic Specialized Scientific and Practical Medical Center of Traumatology and Orthopedics, the patients who underwent osteosynthesis due to the fracture of the hip bone in the area of the hip were analyzed retrospectively, as well as patients after the mathematical modelling program was developed at the base of the center. 43 patients (eighteen men and twenty-two women) with an average age of 42.5 (from 35.0 to 47.6) were included in the study. X-rays, computer tomography, general blood tests and vitamin D and Ca levels in the blood were determined in the patients before the operation. During the surgical procedure, the patients underwent X-ray examination of the pelvic area through the interoperative EOC (Electron Optical Converter), in order to evaluate after the surgical procedure, the state of the metal structure and the blocking rod. To assess hemodynamic, a general blood analysis was performed.

All patients underwent computed tomography examination before surgery, 22 patients (12 women and 10 men) were prospectively included in the study, and based on the results of their computed tomography examination, osteosynthesis was performed using the pre-surgical mathematical modeling method.

Mathematical modelling. This program was developed by the staff of the Republican Specialized Scientific and Practical Medical Center of Traumatology and Orthopedic and registered by the Ministry of Justice of the Republic of Uzbekistan under the number DGU 25373.


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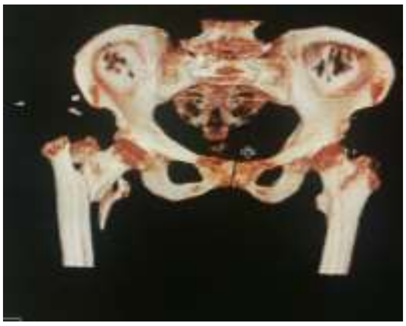
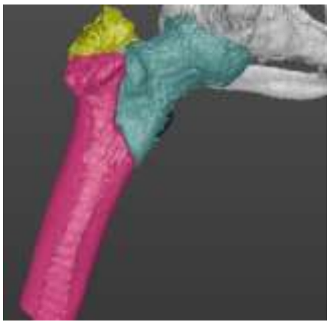
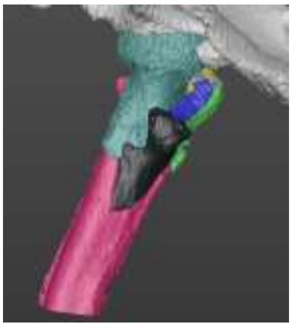
In this case, before the osteosynthesis procedure, patients are taken in 3D format of the bone with the help of MSCT, which gives the opportunity to rotate the bone position in 360 degrees and take a 3D image of the bone. Fractures of femur bones are marked with separate colors. Femur bones are repositioned with the help of the program, and on this repositioned femur, implants and different sizes of implants are placed virtually and the most suitable size is determined.

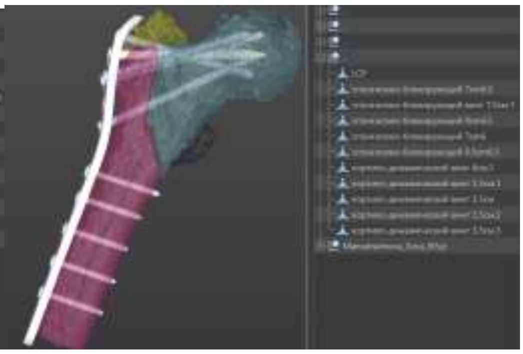



Figure 1 Patient M.S. 64 years old. Diagnosis: The intertrochanteric left femur fracture are crushed and the bone fragments move. (AO 31-A2.2)

Calculation of lost blood volume. The amount of lost blood was measured based on the hematocrit values before and after surgery. That is, it was calculated based on hematocrit indicators before and after surgery.

Gross formula: Estimated volume of blood loss (ml) = Total blood volume (ml) x (post-surgery hematocrit Hct) - (pre-surgery hematocrit Hct)/ pre-surgery hematocrit Hct. In this formula, the total blood volume is calculated as 70 ml of blood per 1 kg of weight.

Statistical analyses. Since all data on age, sex, body mass index, time spent in surgery, lost time in surgery were normally distributed, the differences between the two groups were checked using Student's t-test. Differences were considered statistically significant when $p < 0.05$. All statistical analyzes were performed in Microsoft Excel version 16.0 and JMP pro version 15.

RESULTS

The characteristics of the patients are described in Table I, and the age and gender of the patients in both groups did not differ significantly, and it was found that p=0.456 and p=0.299, respectively. The body weight index (BMI) of the study group was slightly lower than that of the control group, but this difference was considered to be clinically insignificant due to its small size (p = 0.048).

Indications before and after surgery:

Average indicator and standard deviation ± SD

I-table

	Modelled group	Control group	p-value
Number of patients (Abs)	22	18	
Average age (years, SD)	45 ± 4.5	44.5 ± 5.5	0.456

Gender (female: male)	12:10	11:7	0.299
Body mass index kg, SD	28.6 ± 10.7	29.5 ± 6.2	0.048

However, when comparing the results shown in Table 2, that is, the time spent in surgery and the amount of blood lost during surgery, a statistical difference was found. In the statistical analysis, it can be seen that the time to surgery was reduced by 30.5 minutes from 105.6 (SD12.9) to 75.1 (SD10.4) when $p<0.001$. It can be seen that the volume of blood lost during surgery decreased significantly ($p<0.005$), that is, from 380 (SD 98.0) to 298 (SD 128.0), it decreased by 118 ml.

Indications after surgery: Mean and standard deviation ± SD

II-table

	Modeled group	Control group	p-value
Mean time to surgery (min, SD)	75.1 (10.4)	105.6 (12.9)	< 0.001
Volume of blood lost during surgery (ml, SD)	298 (SD 128.0)	380 (SD 98.0)	< 0.005

DISCUSSION

Preoperative planning for trochanteric fractures of the femur is one of the most important factors for reducing complications in the short term and postoperative period. In traditional surgical practice, surgery is planned only based on X-ray and MSCT data, and this has the following disadvantages:

Due to the lack of a complete, i.e. 3D image of the femoral head, pre-surgical planning is based only on primary MSCT data, and this requires additional physical examinations during surgery. As a result of this, the time of surgery and the size of the wound increases, and the amount of blood lost during the surgery increases.

Another disadvantage is that the implants are not placed according to their anatomical characteristics, that is, they are placed on the front-side surface of the femur instead of on the side surface of the plates. In the practice of blocking intramedullary osteosynthesis, when creating a tunnel from the big breast to the bone canal through a trocar, there are cases where the top of the big breast falls not from the inner surface, but from the back surface, from the neck of the femur. Due to improper positioning of the implants, the displacement of the screws causes the screws to come out of the back and front wall of the femoral head. This causes pain in the hip joint and restricts the movement of the joint. In such cases, severe complications such as post-traumatic coxarthrosis and aseptic necrosis of the femoral head may occur in the patient after surgery.

With the help of our program, it is possible to obtain a 3D image of the femoral head, and it is possible to join the fracture fragments virtually, which facilitates the pre-surgical planning process. This gives the opportunity to virtually obtain the exact dimensions of the hip bone implant and implants, and to place the implant in the exact place. At the same time, it helps to reduce the time required for the above-mentioned surgery, the size of the surgery, and the complications during and after the surgery.

CONCLUSION

The obtained results show that pre-surgical mathematical modelling of trochanteric fractures of the femur helps to significantly reduce the time required for surgery and the amount of blood lost during surgery. At the same time, it ensures effective surgical procedure.

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