

УДК 616.718.4-001.5-001.45-089.881(045)

DOI: <http://dx.doi.org/10.15674/0030-5987202535-11>

Analysis of the stress-deformed state of the femur with gunshot fracture with various methods of its fixation

I. A. Lurin^{1,2}, O. A. Burianov³, Y. O. Yarmoliuk^{3,4}, B. V. Matviichuk^{3,5}

¹ National Academy of Medical Sciences of Ukraine, Kyiv

² SSI «Center for Innovative health Technologies» of the State Administration of Affairs, Kyiv, Ukraine

³ Bogomolets National Medical University, Kyiv, Ukraine

⁴ National Military Medical Clinical Center «Main Military Clinical hospital», Kyiv, Ukraine

⁵ Military Medical Clinical Medical treatment and Rehabilitation Center, Irpin', Ukraine

The standard method for stabilizing diaphyseal gunshot fractures of the femur (GFF) is external fixation using a rod apparatus (ex-fix). Objective. To perform a comparative analysis of the biomechanical effectiveness between conventional ex-fix fixation and a modified «ex-fix + intramedullary spacer» design by assessing the stress-strain state of the femur with a midshaft gunshot fracture. Methods. A finite element model of a midshaft femoral gunshot fracture was developed. Two fixation scenarios were simulated: standard rod-based ex-fix, and a combined system using an intramedullary spacer and an ex-fix rod apparatus. Displacement, stress, strain and safety factor were chosen as the effects studied. Results. Conventional fixation resulted in significant stress concentrations at the fracture site (62.4 MPa) and high deformation levels (215.9), exceeding the strength threshold of cortical bone. This may lead to fragment instability and femoral axis misalignment. Rod exit points showed deformation (121,1), contributing to loosening, inflammation in adjacent soft tissues, and overall instability of the fixation system. In contrast, the addition of an intramedullary spacer redistributed stress more evenly, reduced the mechanical load on bone tissue, and improved structural integrity. The combined «spacer + ex-fix» configuration demonstrated superior performance in minimizing deformation and fragment displacement. Conclusions. Finite element modeling confirmed that the «bone + ex-fix + spacer» system outperforms the traditional «bone + ex-fix» configuration in key parameters: displacement, stress, deformation, and safety margin.

Стандартним методом фіксації в разі діафізарних вогнепальних переломів стегнової кістки (ВПСК) є стрижневий апарат зовнішньої фіксації (АЗФ). Мета. Провести порівняльний аналіз фіксації стегнової кістки стрижневим АЗФ і модифікованою конструкцією «стрижневий АЗФ + інтрамедулярний спейсер» шляхом дослідження напружено-деформованого стану стегнової кістки в разі вогнепального перелому в середній третині. Методи. Побудовано скінченно-елементну модель ВПСК у середній третині. Фіксацію здійснювали двома способами: стрижневим АЗФ і комбінацією інтрамедулярного спейсера та стрижневого АЗФ. Досліджуваними показниками було обрано переміщення, напруження, деформацію та запас міцності. Результати. Виявлено, що класична фіксація кісткових уламків за ВПСК у середній третині за допомогою стрижневого АЗФ спричиняє значне напруження в зоні перелому (62,4 МПа) та деформацію (215,9), які перевищують межу міцності кісткової тканини. Це може призводити до нестабільності уламків і порушення осі сегмента кінцівки. Деформація кістки в місцях виходу стрижнів (еквівалент 121,1) викликає їхнє розхитування, що спричиняє запальні процеси в навколишніх м'яких тканинах і загальну нестабільність фіксаційної системи. Запровадження внутрішнього фіксатора в комбінації з АЗФ забезпечує рівномірніший розподіл напружень у моделі, знижує навантаження на кістку та збільшує запас її міцності. Ефективнішим рішенням, згідно з критеріями мінімізації деформації та переміщення уламків, виявилась система фіксації типу «інтрамедулярний спейсер + стрижневий АЗФ». Висновки. За результатами комп'ютерного моделювання виявлено, що система «кістка + АЗФ + спейсер» має перевагу над системою «кістка + АЗФ» за досліджуваними показниками: переміщення, напруження, деформація та запас міцності. Ключові слова. Вогнепальний перелом стегнової кістки, напружено-деформований стан, моделювання.

Keywords. Gunshot femoral fracture; stress-strain state; simulation

Introduction

In modern combat operations, limb injuries account for up to 62.6 % of surgical casualties. Of these, lower limb injuries occur in 58 % of cases, and upper limb injuries in 42 % [1–3]. The proportion of thigh injuries in the structure of combat trauma ranges from 13.6–28.3 %, of which 16.2–22.3 % are diagnosed with a femur fracture [4–6]. Diaphyseal gunshot fractures of the femur (GFF) account for 81.4 % of such injuries and are accompanied by primary bone defects in 79.3 % of cases [7–9].

The standard fixation method for diaphyseal GFF is an external fixation rod (EFR), consisting of a beam and six Schantz rods — three proximal and three distal to the fracture zone [10–12]. Despite its prevalence, this design has a number of significant drawbacks: instability in prolonged use due to micro-deformations of the bone in the areas of rod passage [13, 14]; functional limitations, complicating the rehabilitation process; the likelihood of bone deformations due to uneven load distribution; psycho-emotional discomfort of patients [15, 16].

These issues reduce the effectiveness of treatment and require the development of more stable, biomechanically sound methods for fragment fixation that also do not complicate access to the wound area.

Objective: to conduct a comparative analysis of femoral fixation with an external fixation rod device and a modified design “external fixation rod device + intramedullary spacer” by studying the stress-strain state of the femur in a gunshot fracture in the middle third.

Material and methods

A finite element model of the femur was constructed, a multifragment (7 intermediate parts) gunshot fracture in the middle third was simulated (Fig. 1). The intermediate bone fragments had partial contact with each other, with the proximal and distal fragments of the femur. In the diaphyseal part, the minimum bone diameter was 3.3 cm, the width of the bone-medullary canal was 1.5 cm. In the zones of the transition of the diaphysis to the metaphysis, the diameters increased according to anatomical features.

Two methods of fixation were analyzed: rod EFR, a combination of an intramedullary spacer and rod EFR.

The intramedullary spacer consists of a 0.5 cm thick frame made of surgical steel (AISA 316), covered with bone cement (polymethyl methacrylate). The total thickness of the spacer is 1.0 cm. A metal loop is placed at its proximal end, which allows im-

plantation and removal of the fixator (Fig. 7, 10). The proximal end of the spacer is located in the area of the greater trochanter of the femur; the distal end is 2.0 cm above the articular surface. External fixation rods with a diameter of 0.5 cm are inserted into the metaphyseal areas of the bone, bicortically, in the areas of expansion of the bone-medullary canal, past the trajectory of the spacer.

During modeling, the material was considered homogeneous and isotropic. Its mechanical characteristics were selected according to technical literature [17–20]. The following physical and mechanical parameters were used for the analysis: E — modulus of elasticity (Young's modulus), ν — Poisson's ratio (Table 1).

An example of an anatomical femur was obtained by converting a computer tomogram into a solid-state model using the IntelliSpace Portal software. The 3D model was imported into the Solidworks 19 software. The mathematical mesh was created using the triangulation method. The stress-strain state of the models was calculated using the SimSolid software.

The finite element method was used to analyze the stress-strain state of biomechanical models. The boundary conditions were set using the Structural linear function: the distal articular surface of the femur was rigidly fixed (immoveable function); sliding fixation was applied in the area 1.0 cm distal to the articular surface. A force of 400 N was statically applied to the proximal end of the femur using the Force/Displacement function (Fig. 2). A triangular mesh with Gaussian points was automatically created. The studied effects were displacement, stress, deformation, and safety margin. A system of linear equations of equilibrium of finite elements was solved to determine the components of displacement in each node. The obtained results were then used to calculate the components of equivalent deformation, which is a generalized value, taking into account its various types, i. e. shear, compression, tension.

The magnitudes of stresses were compared at control points, namely: the zone of gunshot fracture and the area of entry of the external fixation rods into the bone, under the conditions of two variants of femur fixation.

The maximum level of stresses in different parts of the femur and fixators, the magnitude of equivalent deformation and displacement of bone fragments at control points, the safety margin of bone tissue and elements of the fixation system were studied.

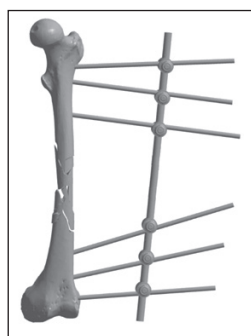


Fig. 1. Model of femur with gunshot fracture, fixed with an EFR

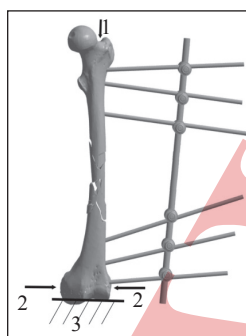


Fig. 2. Points and directions of force application to the femur model fixed with an EFR: 1 — point of force application of 400 N; sliding (2) and rigid (3) fixation of the bone

Table 1

Physical and mechanical properties of the materials used

Material	Young's modulus, E, MPa	Poisson's ratio, ν	Safety margin, R_{na} , MPa
Cortical bone layer	17 600	0.30	170
Cancellous bone layer	500	0.28	10
Surgical steel AISI 316	200 000	0.30	505
Bone cement	1,82	0.18	70

To assess the safety margin of fixing metal elements, the formula (during stressing according to von Mises) (1) was used:

$$K_s = R_{na} / \sigma_a, \quad (1)$$

where K_s is the safety margin; R_{na} is the normal strength limit of the material; σ_a is the stress in the material from normal loads.

Since bone tissue behaves as a biomaterial with plastic characteristics, the shear strength was studied according to formula (2):

$$\tau_{ss} = F/A, \quad (2)$$

where τ_{ss} — shear strength; F — force at which the specimen fails; A — cross-sectional area of the specimen.

According to the technical literature, the threshold value of K_s and τ_{ss} is 1.0. In the case of indicators less than 1.0, the material begins to fail [18–20].

Results

At the first stage of the study, the stress-strain state of the femur model with a gunshot multifragment fracture in the middle third with an EFR under the action of an applied force was studied. When a force of 400 N is applied to the femur fixed with an EFR, a displacement of bone fragments of 10.5–11.7 mm occurs in the fracture zone (Fig. 3).

The next step was to study the stresses in the femur and the fixing elements (Fig. 4).

According to the image, the stress is distributed throughout the femur, ranging from 9.4 to 62.4 MPa. The highest stress is observed in the fracture zone, at 62.4 MPa.

The deformation that occurs in the femur when a force is applied was studied (Fig. 5).

The maximum deformation concentrated in the fracture zone is 215.9. At the exit points of the external fixation rods in the femur, the equivalent deformation is 121.1.

The margin of safety of the femoral bone tissue in a gunshot fracture in the middle third is shown in Fig. 6.

When applying force, the value of the margin of safety of the bone tissue in the gunshot fracture zone is below 1.0, which can lead to its further destruction.

The study has shown that when using the EFR for fixation of bone fragments in the case of applied force, excessive stress occurs in the bone tissue and fixing elements, which leads to bone deformation and a decrease in the margin of safety of the tissue. At the same time, the EFR does not allow to fully ensure stability during loading.

In the case of using the femoral fixation system “EFR + intramedullary spacer” (Fig. 7), with an applied force of 400 N, fragments move within it (Fig. 8).

In the areas of the femur fixed by the “EFR + intramedullary spacer” system, the move ranges from 0.32 to 1.38 mm.

The stress that occurs in the femur fixed by the “EFR + spacer” system is shown in Fig. 9. It is distributed evenly throughout the bone and is 12.6–13.1 MPa.

When a force of 400 N is applied, the maximum stress occurs at two points of the spacer in the zone

of the gunshot fracture. According to the infographic, it is 26.5 and 20.4 MPa (Fig. 10). It is noteworthy that the femur is unloaded. The maximum stress that occurs in the zone of the fracture is 13.1 MPa.

The deformation of the femur, fixed with an EFR and an intramedullary spacer, is shown in Fig. 11.

The deformation of the femur under the conditions of its gunshot fracture, fixation of bone fragments by the “EFR + intramedullary spacer” system, according to the infographic, is insignificant, 38.5 for the bone, 124.1 for the spacer.

When calculating the safety margin of the spacer, the following data were obtained: maximum stress 26.5 MPa, $K_z = 19.1$, i. e. the safety margin is sufficient.

The results of the analysis of the safety margin of bone tissue fixed by the “EFR + spacer” system are shown in Fig. 12.

The safety margin of the bone is in the range from 1.20 to 1.28. It follows that the main load falls on the intramedullary spacer.

A comparison between femoral bone fragment fixation using an EFR alone and the combined approach of “EFR + intramedullary spacer” yields the following conclusions. In the first variant, the main load falls on the femur; the EFR partially stabilizes the fragments, as evidenced by the displacement and stress indicators. In the second, the intramedullary spacer is an internal frame, strengthens the bone tissue and prevents deformation and instability under the influence of applied force.

The computer analysis has shown that the system “femur + EFR + spacer” outperforms “femur + EFR” in terms of displacement, stress, deformation, and safety margin (Table 2).

Discussion

During the treatment of wounded with diaphyseal gunshot fractures of the femur, the fragments are initially fixed with a rod external fixation device, which may contain two or three rods proximally and distally from the injury zone, as well as one or two beams. According to modern studies, the amount of movement

of bone fragments during fixation with EFRs is affected by the distance both from the bone to the support and between the extreme rods with which the fragment is fixed. The number of rods (two or three) does not actually affect the movement indicator [16, 21].

EFRs have a number of advantages over other fixators due to minimal tissue trauma and speed of the operation. They can serve as not only the primary method of fixation, but also the final method of treatment, provided that the bone fragments are repositioned and stable.

In case of multifragmentary fracture of the diaphyseal part of the femur, there is often a problem in repositioning the fragments and aligning the axis of the segment. For this purpose, the use of an intramedullary spacer makes it possible to restore the position of the main bone fragments around the internal frame. In addition, the results of the studies indicate a positive effect of the local antibacterial effect of intramedullary spacers, which were used to treat osteomyelitis of long bones, which made it possible to shorten its duration and avoid the development of contracture of adjacent joints [22].

The use of combined fixation “spacer + EFR” makes it possible not only to ensure stable fixation of the fragments, but also to create a channel for the future implementation of blocked intramedullary osteosynthesis during conversion.

The study found that classical fixation of bone fragments in a gunshot fracture of the middle third of the femur using EFRs causes significant stress in the area of injury (62.4 MPa) and equivalent deformation (215.9). This can lead to instability of the fragments and disruption of the axis of the limb segment. Deformation of the bone at the exit points of the rods (121.1) causes their loosening, which causes inflammatory processes in the surrounding soft tissues and general instability of the fixation system.

Based on the analysis, it follows that the installation of an internal fixator in combination with EFRs provides a more uniform distribution of stresses in the model, reduces the load on the bone and increases the safety margin.

Table 2

Comparison of physical and mechanical characteristics of femoral fixation using two options

Characteristics	Femur, fixed with an EFR		Femur, fixed with the “EFR + spacer” system		
	bone	EFR	bone	EFR	spacer
Displacement, mm	11.7	14.4	1.4	0.3	1.4
Stress, MPa	62.4	15.4	13.1	13.1	26.5
Strain, units	215.9	121.1	38.6	12.4	124.1
Safety margin, units	0.14	32.80	1.20	40.10	19.10

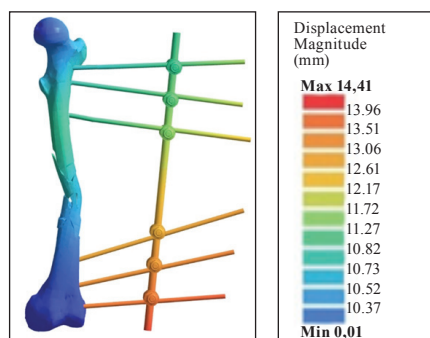


Fig. 3. Movement of femoral fragments under the action of a force of 400 N

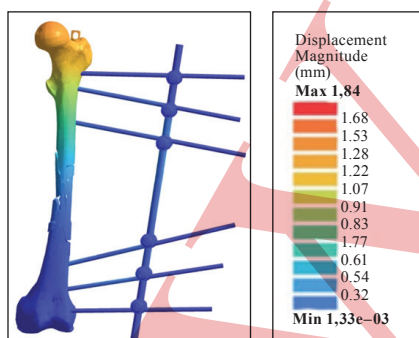


Fig. 8. Movement of bone fragments of the femur fixed with the "EFR + spacer" system

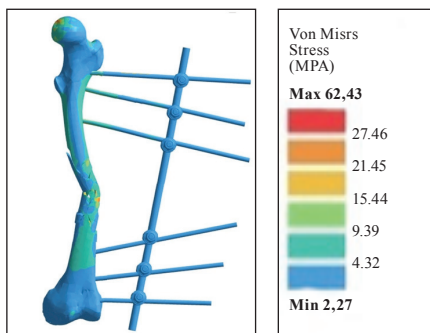


Fig. 4. Stress in the femur and elements of the EFR in force application

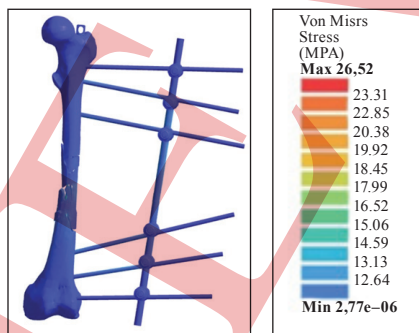


Fig. 9. Stress occurring in the femur fixed with the "EFR + intramedullary spacer" system

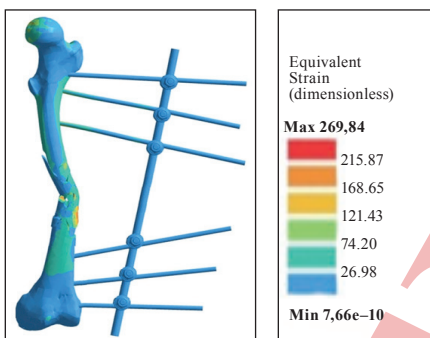


Fig. 5. Deformation occurring in the femur in force application

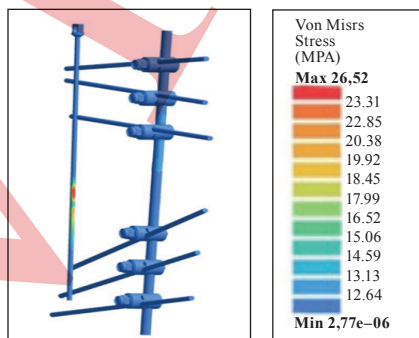


Fig. 10. Stress occurring in the spacer with a force of 400 N applied to the femur with a gunshot fracture

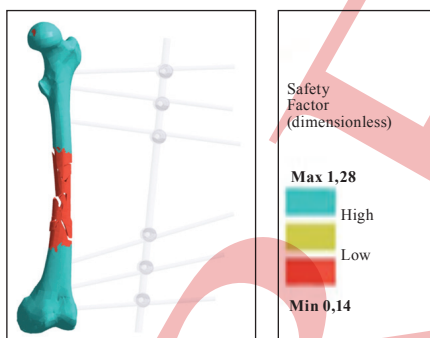


Fig. 6. Safety margin of the femur fixed with an EFR

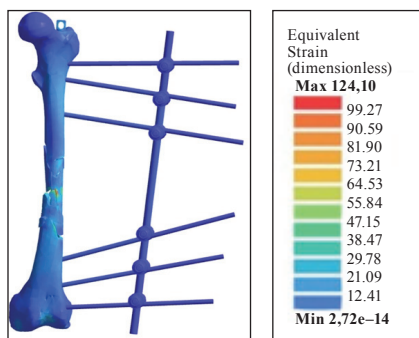


Fig. 11. Deformation of the femur fixed with the "EFR + spacer" system under applied force.

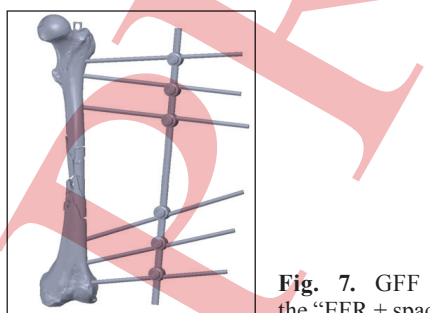


Fig. 7. GFF model fixed with the "EFR + spacer" system

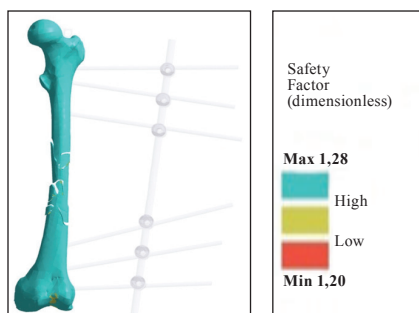


Fig. 12. Safety margin of bone tissue fixed with the "EFR + spacer" system

Conclusions

Comparative analysis of two methods of fixation of bone fragments of the femur has shown that in the case of using EFRs, the main mechanical load falls directly on the femur, while the EFR only partially stabilizes the fragments from displacement and provides uneven distribution of stress. In the combined fixation option “EFR + intramedullary spacer”, the latter performs the function of a frame, significantly increasing the rigidity of the structure and preventing deformation of the femur, loss of stability under the influence of external forces.

The study of the stress-strain state of the femur after its gunshot fracture has revealed that the system “bone + EFR + intramedullary spacer” has an advantage over the system “bone + EFR” in terms of the studied indicators: displacement, stress, deformation and safety margin.

Acknowledgements. The authors are grateful to the specialists of the Biomedical Engineering Laboratory of the State Institution “Institute of Traumatology and Orthopedics of the National Academy of Medical Sciences of Ukraine” for technical support in conducting the study.

Conflict of interest. The authors declare the absence of a conflict of interest.

Prospects for further research. Future studies should focus on comparing different geometries of the rod device for external fixation in combination with an intramedullary spacer, to better understand the mechanical principles behind the optimal design of such a structure. This will help improve fixation techniques, enhance biomechanical stability, and reduce the risk of complications. Additionally, experimental and numerical modeling, particularly using the finite element method, offers promising potential for optimizing device configurations in various clinical scenarios.

Information on funding. The study did not receive external funding.

Authors' contribution. Lurin I. A. — analysis of the findings, critical review of the article, its final approval; Buryanov O. A. — analysis of the findings, final approval of the article; Yarmolyuk Y. O. — review and analysis of related studies, static analysis, critical review of the article; Matviychuk B. V. — review and analysis of related studies, design and modeling, drafting the article.

References

1. Strafun, S. S., Kurinnyi, I. M., Borzyk H, N. O., Tsymbaliuk, Y. V., & Hypunov, V. G. (2021). Tactics of surgical treatment of wounded with guns hot injuries of the upper limb in modern conditions. *Terra Orthopaedica*, (2)109, 10–17. <https://doi.org/10.37647/0132-2486-2021-109-2-10-17> (in Ukrainian)
2. Khomenko, I. P., Korol, S. O., Matviichuk, B. V., & Ustinova, L. A. (2019). Surgical tactics of treatment of the wounded persons with the gun-shot injuries of the hip on all levels of medical support. *Klinicheskaiia khirurgiia*, 86(5), 22–26. <https://doi.org/10.26779/2522-1396.2019.05.22> (in Ukrainian)
3. Dubrov, S., Burianov, O., Omelchenko, T., Vakulych, M., Miasnikov, D., & Lianskorunskiy, V. (2020). Retrospective analysis of treatment outcomes in polytrauma patients with multiple long bone fractures of lower extremities. *Journal of education, health and sport*, 10(2), 327–339. <https://doi.org/10.12775/jehs.2020.10.02.038>
4. Makhubalo, O., Burger, M., Jakoet, S., Van Heukelum, M., Le Roux, N., Gerafa, M., Van der Merwe, S., & Ferreira, N. (2022). Early outcomes of surgically managed civilian gunshot femur fractures at a level one trauma unit in Cape Town, South Africa: A retrospective review. *European journal of trauma and emergency surgery*, 49(2), 859–865. <https://doi.org/10.1007/s00068-022-02138-z>
5. Johnson, D. J., Versteeg, G. H., Middleton, J. A., Cantrell, C. K., & Butler, B. A. (2021). Epidemiology and risk factors for loss to follow-up following operatively treated femur ballistic fractures. *Injury*, 52(8), 2403–2406. <https://doi.org/10.1016/j.injury.2021.06.012>
6. Burianov, O. A., Yarmolyuk, Y. O., Klapchuk, Y. V., Los, D. V., & Lianskorunskiy, V. M. (2022). Does the application of conversion fracture-treatment method and the technology of telemedical movement monitoring affect the long-term results of the treatment of victims with multiple guns hot long bones fractures? *Wiadomości Lekarskie*, 75(12), 3115–3122. <https://doi.org/10.36740/WLEK202212137> (in Ukrainian)
7. Tisnovsky, I., Katz, S. D., & Pincay, J. I. (2021). Management of guns Hot wound-related Hip injuries: A systematic review of the current literature. *Journal of orthopaedics*, 23, 100–106. <https://doi.org/10.1016/j.jor.2020.12.029>
8. Conway, J. D., El Hessy, A. H., Galiboglu, S., Patel, N., & Ges Hef, M. G. (2022). Efficacy of infection eradication in antibiotic cement-coated intramedullary nails for fracture-related infections, nonunions, and fusions. *Antibiotics*, 11(6), 709. <https://doi.org/10.3390/antibiotics11060709>
9. Maqungo, S., Fegredo, D., Brkljac, M., & Laubscher, M. (2020). Gunshot wounds to the hip. *Journal of orthopaedics*, 22, 530–534. <https://doi.org/10.1016/j.jor.2020.09.018>
10. Powell, K. P., Hammouda, A. I., Hlukha, L. P., Rivera, J. C., & Patel, M. (2022). Motorized intramedullary nail lengthening in the older population. *Journal of clinical medicine*, 11(17), 5248. <https://doi.org/10.3390/jcm11175242>
11. Burianov, O. A., Yarmoliuk, Yu. O., Derkach H, S. O., Klapchuk, Yu. V., & Los, D. V. (2023). Optimization of the treatment system for victims with long-bone guns hot fractures. *Trauma*, 24(3), 38–44. <https://doi.org/10.22141/1608-1706.3.24.2023.953> (in Ukrainian)
12. Kazmirchuk, A., Yarmoliuk, Y., Lurin I., Gybalo R., Burianov O., Derkach S. & Karpenko K. (2022). Ukraine's experience with management of combat casualties using NATO's four-tier "Changing as Needed" Healthcare system. *World Journal of Surgery*, 46, 2858–2862. <https://doi.org/10.1007/s00268-022-06718-3>
13. Lurin, A. I., & Tsema, E. V. (2013). Military field surgery. K.: Department of Surgery. (in Ukrainian).
14. Gaiko, G., Khomenko, I., Lurin, I. (2020). Treatment of wounded with combat limb injuries (according to ATO/OGF experience). <https://emed.library.gov.ua/medytsyna-voiennoho-i-povoiennoho-chasu/likuvannia-poranykh-z-boyovymy-travmamy-kintsivok-za-dosvidom-ato-oos-2/> (in Ukrainian)
15. Khomenko, I. P., Korol, S. O., Lurin, I. A., Chelishvili, A. L., & Sichinava, R. M. (2019). Scientific substantiation of the osteosynthesis method conversion in long bones gunshot fractures in the Armed Forces medical system of Ukraine. *World of medicine and biology*, 15(70), 177. <https://doi.org/10.26724/2079-8334-2019-4-70-177-182>
16. Korzh, M., Popsuishapka, O., Lytvysko, V., Shevchenko, I., Doluda, Y., Gubskiy, S., Hrytsenko, A., Mikhanovskiy, D., Marushchak, O., Tokhtamyshev, M., & Arutunan, Z. (2024). Problematic issues of the treatment of diaphyseal gunshot fractures of long bones of extremities. *Orthopaedics traumatology and prosthetics*, (4), 109-120. <https://doi.org/10.15674/0030-598720234109-120>

17. Maganaris, C. N., & Paul, J. P. (1999). In vivo human tendon mechanical properties. *The journal of physiology*, 521(1), 307–313. <https://doi.org/10.1111/j.1469-7793.1999.00307.x>
18. Hvid, I., Christensen, P., Søndergaard, J., Christensen, P. B., & Larsen, C. G. (1983). Compressive strength of tibial cancellous Bone:Instron® and Osteopenetrometer measurements in an autopsy Material. *Acta orthopaedica scandinavica*, 54(6), 819–825. <https://doi.org/10.3109/17453678308992915>
19. Cowin, S. C. (2001). Bone Mechanics handbook. 2nd ed. Boca Raton: CRC Press; 980-980
20. Alloy Wire International. (n.d.). Stainless Steel 316LVM. Retrieved April 17, 2025, from <https://www.alloywire.com/alloys/stainless-steel-316lvm>
21. Popsuishapka, O. K., Subbota, I. A. (2025). Features of deformation of the «debris — external core apparatus» model in case of using structures with different structural geometry. *Orthopedics, traumatology and prosthetics*, (1), 65–74. <http://doi.org/10.15674/0030-59872025165-74>
22. Tanasienko, P., & Kolov, H. (2023). Analysis of the treatment of patients with infectious complications after osteosynthesis. *Experimental and clinical medicine*, 92(2), 14-21. <https://doi.org/10.35339/ekm.2023.92.2.tak>

The article has been sent to the editors 21.04.2025	Received after review 10.05.2025	Accepted for printing 12.05.2025
--	-------------------------------------	-------------------------------------

ANALYSIS OF THE STRESS-DEFORMED STATE OF THE FEMUR WITH GUNSHOT FRACTURE WITH VARIOUS METHODS OF ITS FIXATION

I. A. Lurin ^{1,2}, O. A. Burianov ³, Y. O. Yarmoliuk ^{3,4}, B. V. Matviichuk ^{3,5}

¹ National Academy of Medical Sciences of Ukraine, Kyiv

² SSI «Center for Innovative health Technologies» of the State Administration of Affairs, Kyiv, Ukraine

³ Bogomolets National Medical University, Kyiv, Ukraine

⁴ National Military Medical Clinical Center «Main Military Clinical hospital», Kyiv, Ukraine

⁵ Military Medical Clinical Medical treatment and Rehabilitation Center, Irpin', Ukraine

✉ Igor Lurin, MD, Prof.: lurinnamn@ukr.net; <https://orcid.org/0000-0003-3770-3984>

✉ Olexandr Burianov, MD, Prof.: kaftraum@ukr.net; <https://orcid.org/0000-0002-2174-1882>

✉ Yurii Yarmoliuk, MD, Prof.: Yuo1707@gmail.com; <https://orcid.org/0000-0002-9583-1231>

✉ Bohdan Matviichuk, MD: godtaken.bm@gmail.com; <https://orcid.org/0000-0003-3770-3984>