GEORGIAN MEDICAL NEWS

ISSN 1512-0112

NO 7-8 (340-341) Июль-Август 2023

ТБИЛИСИ - NEW YORK

ЕЖЕМЕСЯЧНЫЙ НАУЧНЫЙ ЖУРНАЛ

Медицинские новости Грузии

საქართველოს სამედიცინო სიახლენი

GEORGIAN MEDICAL NEWS

Monthly Georgia-US joint scientific journal published both in electronic and paper formats of the Agency of Medical Information of the Georgian Association of Business Press. Published since 1994. Distributed in NIS, EU and USA.

GMN: Georgian Medical News is peer-reviewed, published monthly journal committed to promoting the science and art of medicine and the betterment of public health, published by the GMN Editorial Board since 1994. GMN carries original scientific articles on medicine, biology and pharmacy, which are of experimental, theoretical and practical character; publishes original research, reviews, commentaries, editorials, essays, medical news, and correspondence in English and Russian.
GMN is indexed in MEDLINE, SCOPUS, PubMed and VINITI Russian Academy of Sciences. The full text content is available through EBSCO databases.

GMN: Медицинские новости Грузии - ежемесячный рецензируемый научный журнал, издаётся Редакционной коллегией с 1994 года на русском и английском языках в целях поддержки медицинской науки и улучшения здравоохранения. В журнале публикуются оригинальные научные статьи в области медицины, биологии и фармации, статьи обзорного характера, научные сообщения, новости медицины и здравоохранения. Журнал индексируется в MEDLINE, отражён в базе данных SCOPUS, PubMed и ВИНИТИ РАН. Полнотекстовые статьи журнала доступны через БД EBSCO.

GMN: Georgian Medical News – საქართველოს სამედიცინო სიახლენი – არის ყოველთვიური სამეცნიერო სამედიცინო რეცენზირებადი ჟურნალი, გამოიცემა 1994 წლიდან, წარმოადგენს სარედაქციო კოლეგიისა და აშშ-ის მეცნიერების, განათლების, ინდუსტრიის, ხელოვნებისა და ბუნებისმეტყველების საერთაშორისო აკადემიის ერთობლივ გამოცემას. GMN-ში რუსულ და ინგლისურ ენებზე ქვეყნდება ექსპერიმენტული, თეორიული და პრაქტიკული ხასიათის ორიგინალური სამეცნიერო სტატიები მედიცინის, ბიოლოგიისა და ფარმაციის სფეროში, მიმოხილვითი ხასიათის სტატიები.
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WEBSITE

www.geomednews.com

К СВЕДЕНИЮ АВТОРОВ!

При направлении статьи в редакцию необходимо соблюдать следующие правила:

1. Статья должна быть представлена в двух экземплярах, на русском или английском языках, напечатанная через **полтора интервала на одной стороне стандартного листа с шириной левого поля в три сантиметра**. Используемый компьютерный шрифт для текста на русском и английском языках - **Times New Roman** (**Кириллица**), для текста на грузинском языке следует использовать **AcadNusx.** Размер шрифта - **12**. К рукописи, напечатанной на компьютере, должен быть приложен CD со статьей.

2. Размер статьи должен быть не менее десяти и не более двадцати страниц машинописи, включая указатель литературы и резюме на английском, русском и грузинском языках.

3. В статье должны быть освещены актуальность данного материала, методы и результаты исследования и их обсуждение.

При представлении в печать научных экспериментальных работ авторы должны указывать вид и количество экспериментальных животных, применявшиеся методы обезболивания и усыпления (в ходе острых опытов).

4. К статье должны быть приложены краткое (на полстраницы) резюме на английском, русском и грузинском языках (включающее следующие разделы: цель исследования, материал и методы, результаты и заключение) и список ключевых слов (key words).

5. Таблицы необходимо представлять в печатной форме. Фотокопии не принимаются. **Все цифровые, итоговые и процентные данные в таблицах должны соответствовать таковым в тексте статьи**. Таблицы и графики должны быть озаглавлены.

6. Фотографии должны быть контрастными, фотокопии с рентгенограмм - в позитивном изображении. Рисунки, чертежи и диаграммы следует озаглавить, пронумеровать и вставить в соответствующее место текста **в tiff формате**.

В подписях к микрофотографиям следует указывать степень увеличения через окуляр или объектив и метод окраски или импрегнации срезов.

7. Фамилии отечественных авторов приводятся в оригинальной транскрипции.

8. При оформлении и направлении статей в журнал МНГ просим авторов соблюдать правила, изложенные в «Единых требованиях к рукописям, представляемым в биомедицинские журналы», принятых Международным комитетом редакторов медицинских журналов - http://www.spinesurgery.ru/files/publish.pdf и http://www.nlm.nih.gov/bsd/uniform_requirements.html
В конце каждой оригинальной статьи приводится библиографический список. В список литературы включаются все материалы, на которые имеются ссылки в тексте. Список составляется в алфавитном порядке и нумеруется. Литературный источник приводится на языке оригинала. В списке литературы сначала приводятся работы, написанные знаками грузинского алфавита, затем кириллицей и латиницей. Ссылки на цитируемые работы в тексте статьи даются в квадратных скобках в виде номера, соответствующего номеру данной работы в списке литературы. Большинство цитированных источников должны быть за последние 5-7 лет.

9. Для получения права на публикацию статья должна иметь от руководителя работы или учреждения визу и сопроводительное отношение, написанные или напечатанные на бланке и заверенные подписью и печатью.

10. В конце статьи должны быть подписи всех авторов, полностью приведены их фамилии, имена и отчества, указаны служебный и домашний номера телефонов и адреса или иные координаты. Количество авторов (соавторов) не должно превышать пяти человек.

11. Редакция оставляет за собой право сокращать и исправлять статьи. Корректура авторам не высылается, вся работа и сверка проводится по авторскому оригиналу.

12. Недопустимо направление в редакцию работ, представленных к печати в иных издательствах или опубликованных в других изданиях.

При нарушении указанных правил статьи не рассматриваются.

REQUIREMENTS

Please note, materials submitted to the Editorial Office Staff are supposed to meet the following requirements:

1. Articles must be provided with a double copy, in English or Russian languages and typed or compu-ter-printed on a single side of standard typing paper, with the left margin of **3** centimeters width, and **1.5** spacing between the lines, typeface - **Times New Roman** (**Cyrillic**), print size - **12** (referring to Georgian and Russian materials). With computer-printed texts please enclose a CD carrying the same file titled with Latin symbols.

2. Size of the article, including index and resume in English, Russian and Georgian languages must be at least 10 pages and not exceed the limit of 20 pages of typed or computer-printed text.

3. Submitted material must include a coverage of a topical subject, research methods, results, and review.

Authors of the scientific-research works must indicate the number of experimental biological species drawn in, list the employed methods of anesthetization and soporific means used during acute tests.

4. Articles must have a short (half page) abstract in English, Russian and Georgian (including the following sections: aim of study, material and methods, results and conclusions) and a list of key words.

5. Tables must be presented in an original typed or computer-printed form, instead of a photocopied version. **Numbers, totals, percentile data on the tables must coincide with those in the texts of the articles.** Tables and graphs must be headed.

6. Photographs are required to be contrasted and must be submitted with doubles. Please number each photograph with a pencil on its back, indicate author's name, title of the article (short version), and mark out its top and bottom parts. Drawings must be accurate, drafts and diagrams drawn in Indian ink (or black ink). Photocopies of the X-ray photographs must be presented in a positive image in **tiff format**.

Accurately numbered subtitles for each illustration must be listed on a separate sheet of paper. In the subtitles for the microphotographs please indicate the ocular and objective lens magnification power, method of coloring or impregnation of the microscopic sections (preparations).

7. Please indicate last names, first and middle initials of the native authors, present names and initials of the foreign authors in the transcription of the original language, enclose in parenthesis corresponding number under which the author is listed in the reference materials.

8. Please follow guidance offered to authors by The International Committee of Medical Journal Editors guidance in its Uniform Requirements for Manuscripts Submitted to Biomedical Journals publication available online at: http://www.nlm.nih.gov/bsd/uniform_requirements.html
http://www.icmje.org/urm_full.pdf
In GMN style for each work cited in the text, a bibliographic reference is given, and this is located at the end of the article under the title "References". All references cited in the text must be listed. The list of references should be arranged alphabetically and then numbered. References are numbered in the text [numbers in square brackets] and in the reference list and numbers are repeated throughout the text as needed. The bibliographic description is given in the language of publication (citations in Georgian script are followed by Cyrillic and Latin).

9. To obtain the rights of publication articles must be accompanied by a visa from the project instructor or the establishment, where the work has been performed, and a reference letter, both written or typed on a special signed form, certified by a stamp or a seal.

10. Articles must be signed by all of the authors at the end, and they must be provided with a list of full names, office and home phone numbers and addresses or other non-office locations where the authors could be reached. The number of the authors (co-authors) must not exceed the limit of 5 people.

11. Editorial Staff reserves the rights to cut down in size and correct the articles. Proof-sheets are not sent out to the authors. The entire editorial and collation work is performed according to the author's original text.

12. Sending in the works that have already been assigned to the press by other Editorial Staffs or have been printed by other publishers is not permissible.

Articles that Fail to Meet the Aforementioned Requirements are not Assigned to be Reviewed.

ავტორთა საყურადღებოდ!

რედაქციაში სტატიის წარმოდგენისას საჭიროა დავიცვათ შემდეგი წესები:

1. სტატია უნდა წარმოადგინოთ 2 ცალად, რუსულ ან ინგლისურ ენებზე,დაბეჭდილი სტანდარტული ფურცლის 1 გვერდზე, 3 სმ სიგანის მარცხენა ველისა და სტრიქონებს შორის 1,5 ინტერვალის დაცვით. გამოყენებული კომპიუტერული შრიფტი რუსულ და ინგლისურენოვან ტექსტებში - **Times New Roman (Кириллица)**, ხოლო ქართულენოვან ტექსტში საჭიროა გამოვიყენოთ **AcadNusx.** შრიფტის ზომა – 12. სტატიას თან უნდა ახლდეს CD სტატიით.

2. სტატიის მოცულობა არ უნდა შეადგენდეს 10 გვერდზე ნაკლებს და 20 გვერდზე მეტს ლიტერატურის სიის და რეზიუმეების (ინგლისურ,რუსულ და ქართულ ენებზე) ჩათვლით.

3. სტატიაში საჭიროა გაშუქდეს: საკითხის აქტუალობა; კვლევის მიზანი; საკვლევი მასალა და გამოყენებული მეთოდები; მიღებული შედეგები და მათი განსჯა. ექსპერიმენტული ხასიათის სტატიების წარმოდგენისას ავტორებმა უნდა მიუთითონ საექსპერიმენტო ცხოველების სახეობა და რაოდენობა; გაუტკივარებისა და დაძინების მეთოდები (მწვავე ცდების პირობებში).

4. სტატიას თან უნდა ახლდეს რეზიუმე ინგლისურ, რუსულ და ქართულ ენებზე არანაკლებ ნახევარი გვერდის მოცულობისა (სათაურის, ავტორების, დაწესებულების მითითებით და უნდა შეიცავდეს შემდეგ განყოფილებებს: მიზანი, მასალა და მეთოდები, შედეგები და დასკვნები; ტექსტუალური ნაწილი არ უნდა იყოს 15 სტრიქონზე ნაკლები) და საკვანძო სიტყვების ჩამონათვალი (key words).

5. ცხრილები საჭიროა წარმოადგინოთ ნაბეჭდი სახით. ყველა ციფრული, შემაჯამებელი და პროცენტული მონაცემები უნდა შეესაბამებოდეს ტექსტში მოყვანილს.

6. ფოტოსურათები უნდა იყოს კონტრასტული; სურათები, ნახაზები, დიაგრამები - დასათაურებული, დანომრილი და სათანადო ადგილას ჩასმული. რენტგენოგრამების ფოტოასლები წარმოადგინეთ პოზიტიური გამოსახულებით **tiff** ფორმატში. მიკროფოტოსურათების წარწერებში საჭიროა მიუთითოთ ოკულარის ან ობიექტივის საშუალებით გადიდების ხარისხი, ანათალების შეღებვის ან იმპრეგნაციის მეთოდი და აღნიშნოთ სურათის ზედა და ქვედა ნაწილები.

7. სამამულო ავტორების გვარები სტატიაში აღინიშნება ინიციალების თანდართვით, უცხოურისა – უცხოური ტრანსკრიპციით.

8. სტატიას თან უნდა ახლდეს ავტორის მიერ გამოყენებული სამამულო და უცხოური შრომების ბიბლიოგრაფიული სია (ბოლო 5-8 წლის სიღრმით). ანბანური წყობით წარმოდგენილ ბიბლიოგრაფიულ სიაში მიუთითეთ ჯერ სამამულო, შემდეგ უცხოელი ავტორები (გვარი, ინიციალები, სტატიის სათაური, ჟურნალის დასახელება, გამოცემის ადგილი, წელი, ჟურნალის №, პირველი და ბოლო გვერდები). მონოგრაფიის შემთხვევაში მიუთითეთ გამოცემის წელი, ადგილი და გვერდების საერთო რაოდენობა. ტექსტში კვადრატულ ფჩხილებში უნდა მიუთითოთ ავტორის შესაბამისი N ლიტერატურის სიის მიხედვით. მიზანშეწონილია, რომ ციტირებული წყაროების უმეტესი ნაწილი იყოს 5-6 წლის სიღრმის.

9. სტატიას თან უნდა ახლდეს: ა) დაწესებულების ან სამეცნიერო ხელმძღვანელის წარდგინება, დამოწმებული ხელმოწერითა და ბეჭდით; ბ) დარგის სპეციალისტის დამოწმებული რეცენზია, რომელშიც მითითებული იქნება საკითხის აქტუალობა, მასალის საკმაობა, მეთოდის სანდოობა, შედეგების სამეცნიერო-პრაქტიკული მნიშვნელობა.

10. სტატიის ბოლოს საჭიროა ყველა ავტორის ხელმოწერა, რომელთა რაოდენობა არ უნდა აღემატებოდეს 5-ს.

11. რედაქცია იტოვებს უფლებას შეასწოროს სტატია. ტექსტზე მუშაობა და შეჯერება ხდება საავტორო ორიგინალის მიხედვით.

12. დაუშვებელია რედაქციაში ისეთი სტატიის წარდგენა, რომელიც დასაბეჭდად წარდგენილი იყო სხვა რედაქციაში ან გამოქვეყნებული იყო სხვა გამოცემებში.

აღნიშნული წესების დარღვევის შემთხვევაში სტატიები არ განიხილება.

Содержание:

MATHEMATICAL JUSTIFICATION OF THE CHOICE OF RODS FOR EXTERNAL FIXATION DEVICES FOR POLYSTRUCTURAL PELVIC INJURIES

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Abstract.

Aim: In order to fulfill the purpose of biomechanical substantiation for extrafocal pelvic osteosynthesis in osteoporosis we studied the stress-strain state (SSS) of LEG under conditions of external fixation by apparatuses with cylindrical and conical rods.

Material and methods: Studies of the stress-strain state of the lower extremity belt by the finite element method were carried out under conditions of external fixation by devices with cylindrical and conical rods. In the finite element method, the approximate solution is constructed as a superposition of approximating functions. At the first stage of solving the problem, the object is divided into areas of a simpler form - finite elements whose geometric dimensions are significantly smaller than the dimensions of the entire biomechanical system. Modern software systems generate finite elements of the grid automatically using elements with triangular faces in most cases. At the junctions of the elements (nodal points), the real stress field is replaced by the action of forces and movements. The type of finite elements is characterized by the number of nodes and the degree of approximation of unknowns within the domain and largely determines the accuracy of the resulting solution in the finite element method. Various types of biological tissues were taken into account in the conducted studies: compact and spongy bone, cartilage tissue, intervertebral disc, ligaments. In this study, the material was considered homogeneous and isotropic. The main load is body weight. In the calculation, the body weight was taken to be equal to 700 N. The geometric model was built on the basis of tomographic sections of the pelvis carried out through 0.5 – 1 cm for irregular zones. A pelvis with rotationally unstable (type B1 according to AO classification) damage after osteosynthesis by an external fixation device was modeled in the variants of using cylindrical and conical rods. Mises stresses were used to assess the stress state. The resulting model consists of 75,845 finite elements and has 132253 nodes. The construction of the geometric model was carried out in the SolidWorks program. VAT calculations and analysis were carried out in the ANSYS program.

Results and Discussion: In the first variant of the study of the pelvic model with normal bone tissue and cylindrical rods, the calculation results showed that with a single support standing (support on the left limb), the supporting side with pronounced stress concentration zones in the sacroiliac joint, the place of entry of the rod into the bone and in the area of reducing the thickness of the iliac wing is more tense. Two stress concentration zones are observed along the passage of the rod. The most intense is the area of the screw entry into the bone (18.5 MPa). There is also an area of increased stress at the site of a decrease in the thickness of the iliac wing (8.1 MPa), where the rod passes closest to the cortical layers. The calculation of the model using conical shaped rods showed that the nature of the VAT distribution for the model as a whole has not changed, and the stress state level has decreased. So, at the point of entry of the screw into the bone, the value of the Mises stresses is 16.4 MPa, and at the point of reduction of the thickness of the iliac bone – 6.3 MPa. It is worth noting that the area with an increased stress state along the passage of a conical rod is smaller than for a cylindrical one. In the second variant of the study for a pelvic model with osteoporotic bone tissue, a comparative analysis of VAT when using cylindrical rods of an external fixation device showed that the general nature of the distribution of stresses and deformations for the model as a whole did not change, but the VAT level increased. At the point where the screws enter the bone, it is 28.4 MPa, at the point where the thickness of the iliac wing decreases – 9.1 MPa. The level of tension has also increased throughout the "rod-bone" contact. A comparative analysis of VAT for the variant of conical rods of the external fixation apparatus and osteoporotic bone tissue showed that the general nature of the VAT distribution for the model as a whole has not changed, and the level of stress state has increased as well as in the model with cylindrical screws. At the point where the screws enter the bone, it is 26.5 MPa. At the site of the reduction in the thickness of the iliac wing, the stress level is 7 MPa.

Conclusions: The use of conical shaped rods in the external fixation device of the pelvis makes it possible to reduce the level of stress-strain state both in the area of the entry of screws into the bone and in the area of the thinnest part of the iliac wing. For external osteosynthesis of the pelvis in polystructural injuries, lowering the stress state when using conical rods plays an important role, since the strength characteristics of osteoporotic bone tissue are significantly lower than those of normal. Thus, the use of conical rods in external pelvic fixation devices improves the strength characteristics of the "pelvis – rod" system, which makes it possible to recommend their testing in clinical practice.

Key words. Osteoporosis, pelvis, external fixation, mathematical justification, cylindrical or conical rod.

Introduction.

Immobilization of the lower extremity girdle (LEG) is an essential prerequisite for an effective treatment of polystructural pelvic injuries (PPI). The selection criteria for the method of stabilization of LEG should be reliability of fixation, speed, and ease of use, since the process of operation should not aggravate both the general condition of the injured person and the course of the traumatic disease. Immobilization of the lower extremity girdle In the acute phase of the injury these requirements to the greatest extent are met by the method of extrafocal osteosynthesis, which has become widespread with polystructural pelvic injuries PPI [1-3]. But the fixing properties of the rod devices depend on the risk of violation of the structural and functional state of the bone tissue since the effect of fractures on its mineral density is known [4-10].

In addition, injuries of organs of the digestive, endocrine, and genitourinary systems, located in the pelvic cavity, cannot but affect the risk of developing osteopoenia and osteoporosis. An early development of osteoporotic changes in the iliac ilae, characteristic of PPI, exerts a negative effect on the strength characteristics of the pelvis-rod system [8,11-13].

The aim of the study was the biomechanical substantiation of extra-focal pelvic osteosynthesis in osteoporosis.

Materials and Methods.

The stress-strain state (SSS) of the lower extremity belt was studied by the finite element method (FEM) under conditions of external fixation by devices with cylindrical and conical rods. In FEM, an approximate solution is constructed in the form of a superposition of approximating functions. For solving the above problem, at the first stage the object is divided into areas of a simpler form, finite elements (FE), whose geometric dimensions are much smaller than those of the entire biomechanical system [14].

Modern software systems generate FE cells automatically using in most cases elements with triangular faces. At junctions of the elements (nodal points) the real stress field is replaced by the action of forces and displacements.

The type of FE is characterized by the number of nodes and the degree of approximation of the unknowns within the region and largely determines the accuracy of the obtained FEM solution. The elements used in building the calculation model are presented in Figure 1.

The studies took into account different types of biological tissues: compact and cancellous bone, cartilage tissue, intervertebral disc, ligaments. In this study, the material was considered to be homogeneous and isotropic. The elastic modulus (Young's modulus E) and Poisson's ratio ν for different materials are summarized in Table 1.

The body weight is the main load. In the calculation, the body weight was taken equal to 700 N. The values of the resulting forces for the pelvis were taken in accordance with the data given in [15,16].

The geometric model was built on the basis of tomographic sections of the pelvis, drawn through 0.5-1 cm for irregular zones. The pelvis was modelled with a rotationally unstable injury (type B1 according to AO classification) after osteosynthesis with an external fixation device in versions of using cylindrical and conical rods (Figure 2).

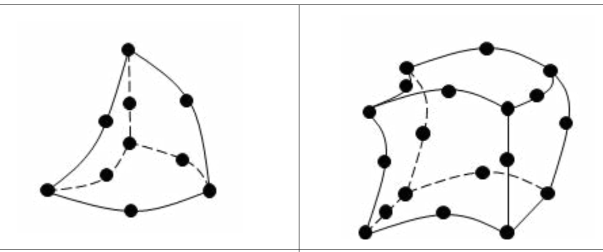
In order to estimate SSS, von Mises stresses were used. The obtained FE model (Figure 3) consisted of 75845 FE and had 132253 nodes. The geometric model was built in the SolidWorks program. The calculations and analysis of SSS were carried out in the ANSYS program.

Results and Discussion.

In the first version of the study of the pelvic model with the normal bone tissue and cylindrical rods, the calculation results showed (Figure 4) that with a single-limb support (the left limb support) more stress was observed on the supporting side with pronounced zones of stress concentration in the region of the sacroiliac joint, at the site of entry of the rod into the bone and in the area of a reduced thickness of the iliac ala.

Table 1. *Mechanical characteristics of biological tissues.*

Tissue	**E (MPa)**	ν
Compact bone	18350	0.3
Osteoporotic compact bone	1500	0.3
Cancellous bone	330	0.3
Osteoporotic cancellous bone	150	0.3
Cartilage	10.5	0.49
Intervertebral disc	4.2	0.45
Ligaments	50	0.45



a) 10-noded tetrahedron with quadratic approximation

b) 20-noded prism with quadratic approximation

Figure 1. *Types of FE.*

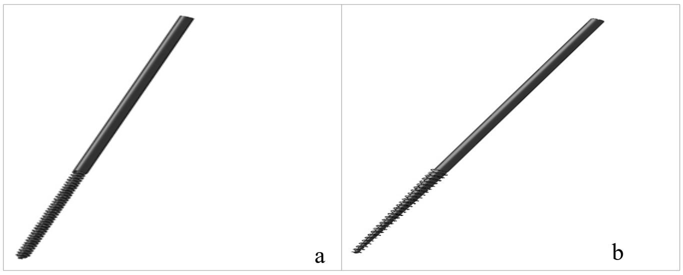


Figure 2. *Cylindrical (a) and conical (b) rods are used in a device for external fixation of the pelvis.*

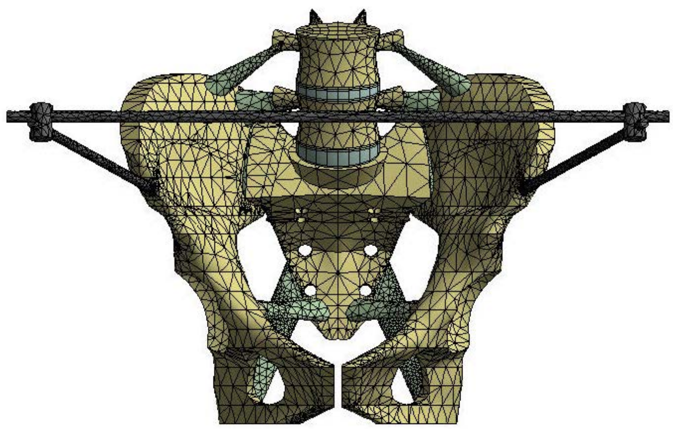
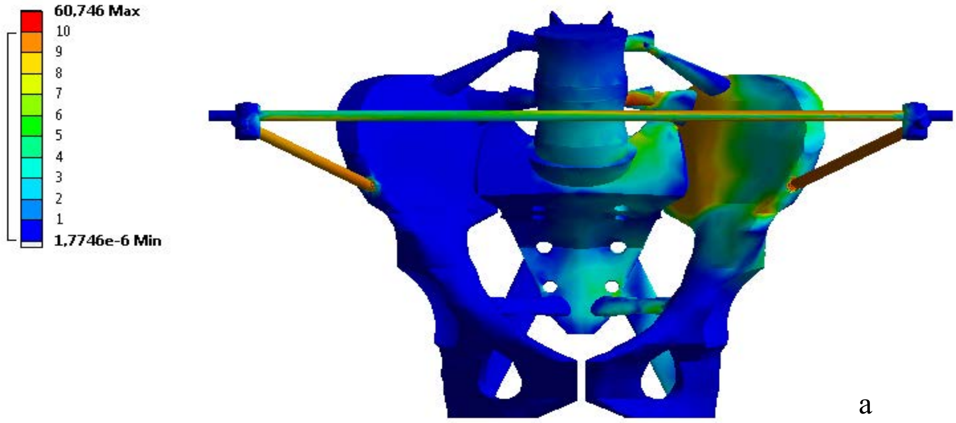


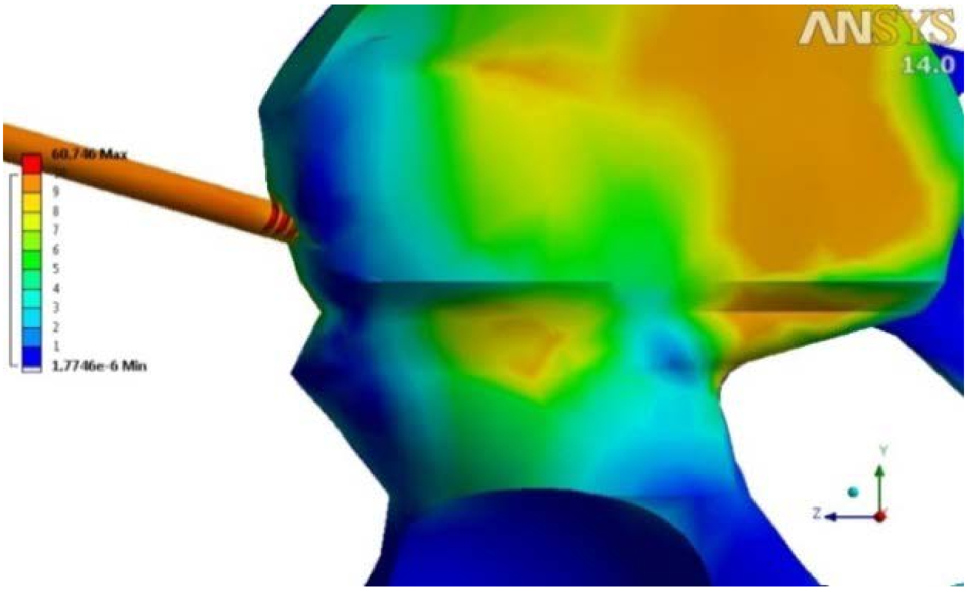
Figure 3. *FE calculation model of the pelvis.*

Along the passage of the rod (Figure 5), two stress concentration zones were observed. The most intense was the area where the screw enters the bone (18.5 MPa). An area of increased stress was also observed at the site of reduced thickness of the iliac ala (8.1 MPa), where the rod passed most closely to the cortical layers.

The calculation of the model using conical rods showed (Figure 6) that the nature of SSS distribution for the model



a



b

Figure 4. *Von Mises stress in the calculation model: a) front view; b) left view.*

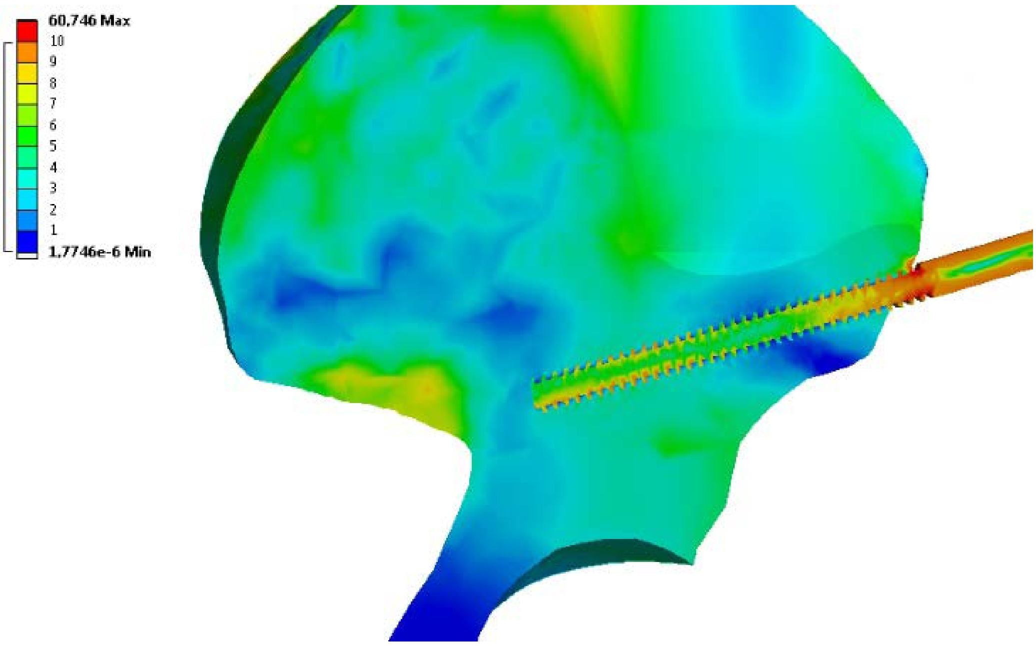


Figure 5. *Zones of stress concentration along the passage of a cylindrical rod.*

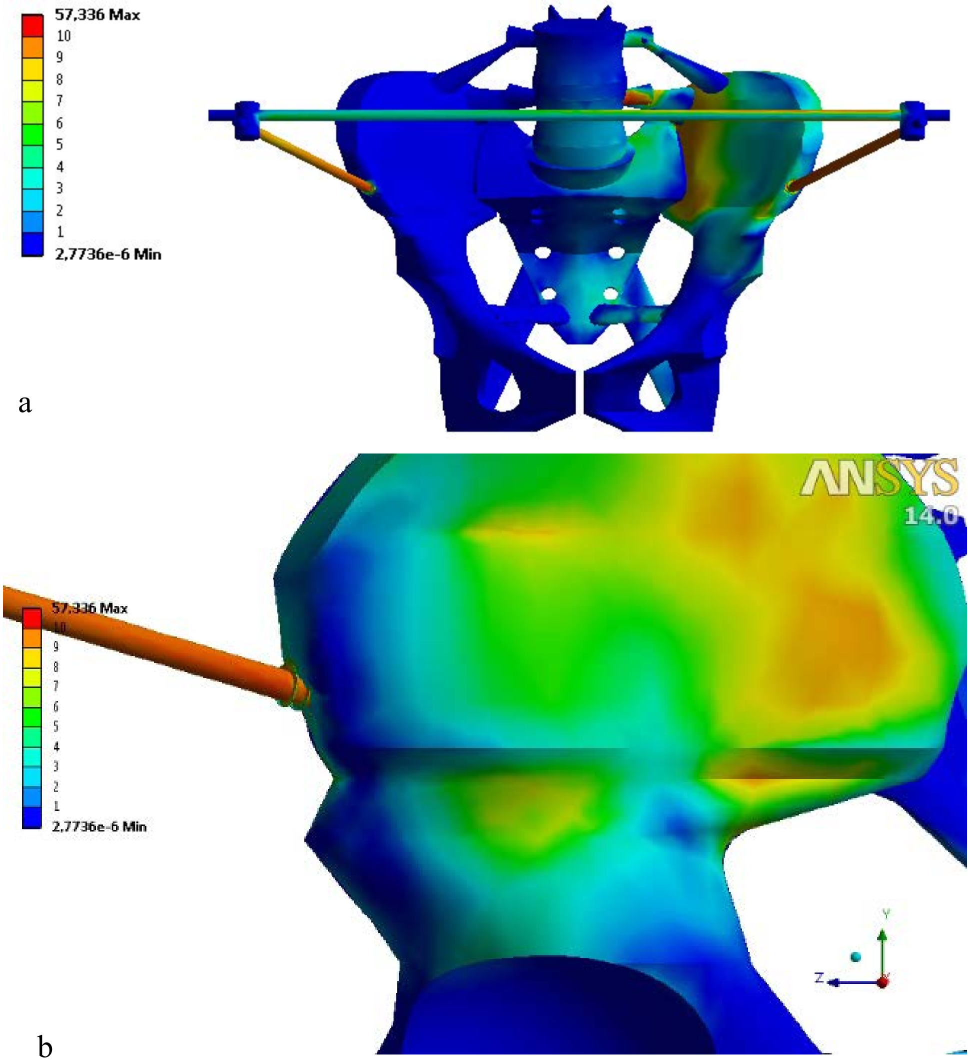


Figure 6. *Mises stress in the calculation model: a) front view; b) left view.*

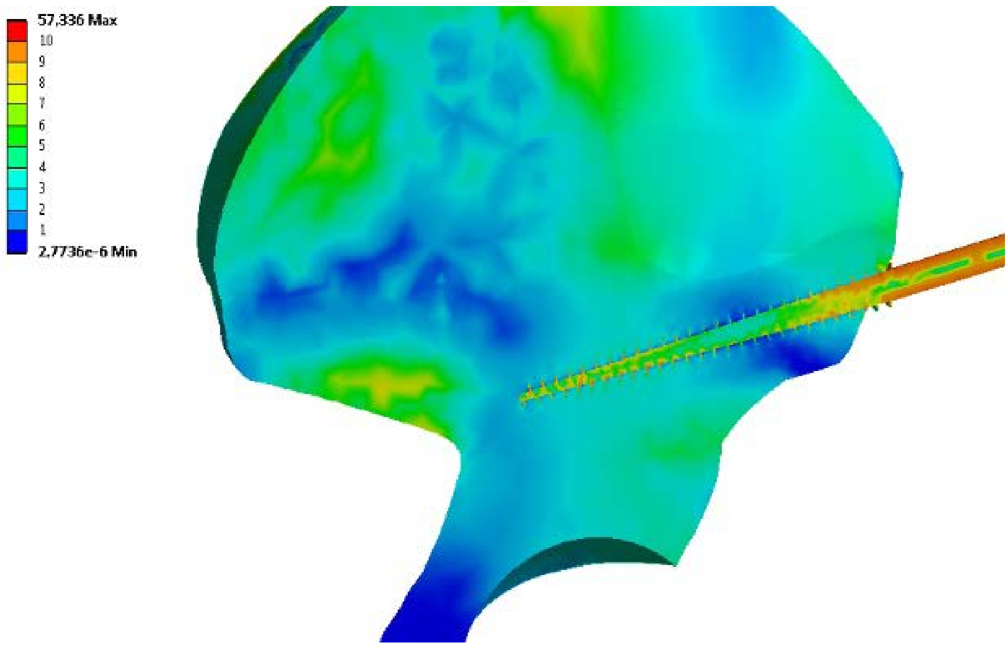


Figure 7. *An area with an increased SSS of the ilium along the passage of a conical rod.*

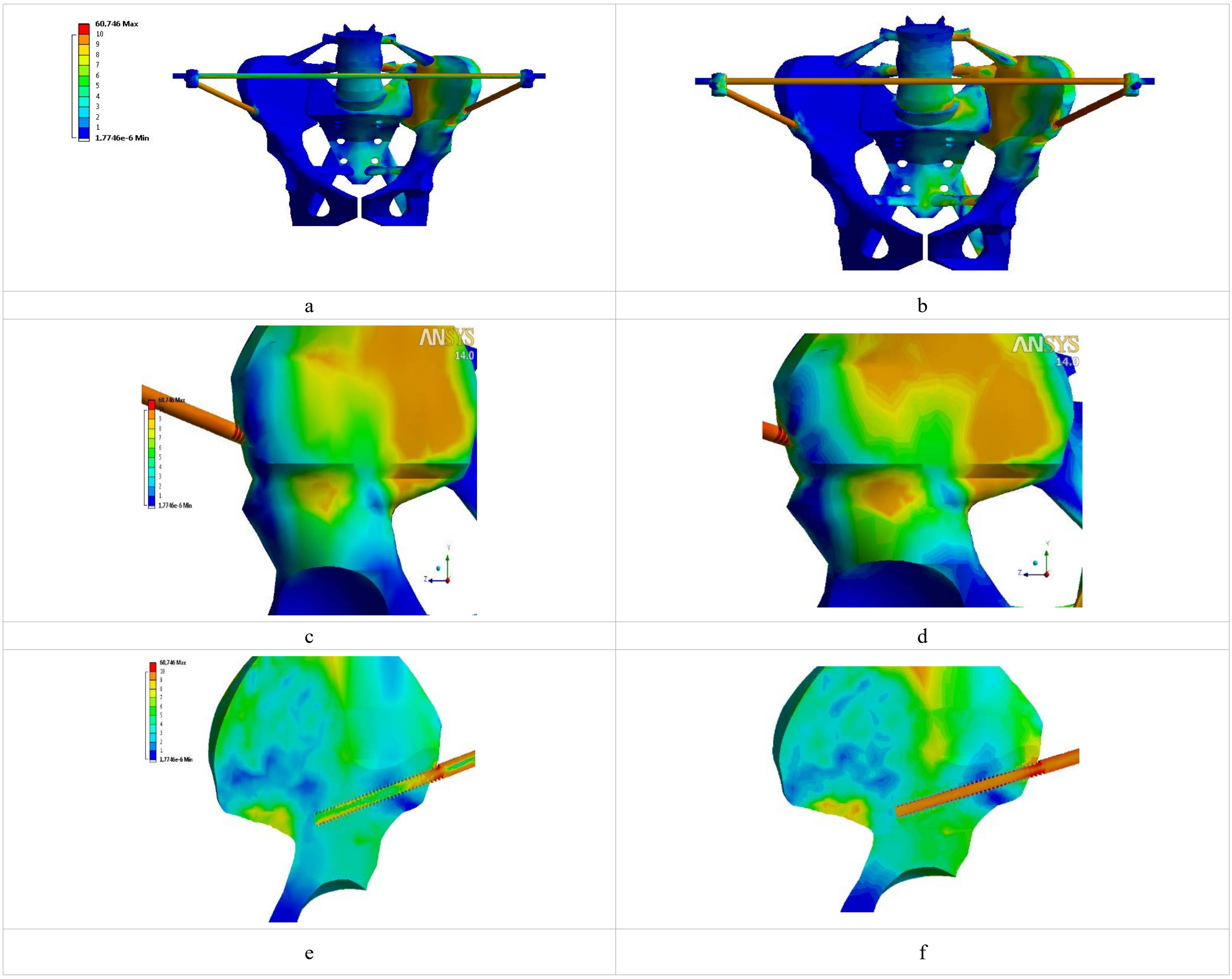


Figure 8. *SSS models of the pelvis with the osteoporotic bone tissue using cylindrical rods of an external fixation device.*

as a whole had not changed, and the level of stress state had decreased. Thus, in the area where the screw entered the bone, the von Mises stress was 16.4 MPa, it being 6.3 MPa in the area of reduced thickness of the ilium. It should be noted that the region with an increased stress state along the passage of a conical rod was smaller than for a cylindrical one (Figure 7).

In the second version of the study, for a model of the pelvis with the osteoporotic bone tissue, a comparative analysis of SSS using cylindrical rods of an external fixation device showed that the general distribution of stress and strain for the model as a whole did not change, but the level of SSS increased (Figure 8a-d).

It was 28.4 MPa in the area of entry of the screws into the bone and 9.1 MPa at the site of reduced thickness of the iliac wing. The level of the stress state also increased throughout the entire "rod-bone" contact (Figure 8e,f). A comparative analysis of SSS for the version with conical rods of an external fixation device and the osteoporotic bone tissue showed that the general character of SSS distribution for the model as a whole had not changed, but the level of stress state had increased as well as in the model with cylindrical screws (Figure 9). In the area where the screws entered the bone, it was 26.5 MPa. In the area of reduced thickness of the iliac ala the level of stress was 7 MPa.

Figure 10 shows a comparison of SSS in the iliac section for cylindrical and conical rods with the normal and osteoporotic bone tissue.

Conclusion.

The mathematical model, taking into account osteoporosis, differs from the model with normal bone tissue by changing the physical properties of materials (bone tissue), namely, by other values of the elastic modulus E (Young's modulus). This parameter, under unchanged other conditions (the geometry of the model and its loading), leads to a change in the stress state. For osteoporotic bone tissue, destruction occurs when lower stresses are reached (120 MPa - normal cortical bone tissue, 75 MPa - osteoporotic bone tissue, and for normal spongy tissue, the tensile strength is 6.6 MPa and 3.3 MPa for osteoporotic). Those, the study of models with altered bone properties

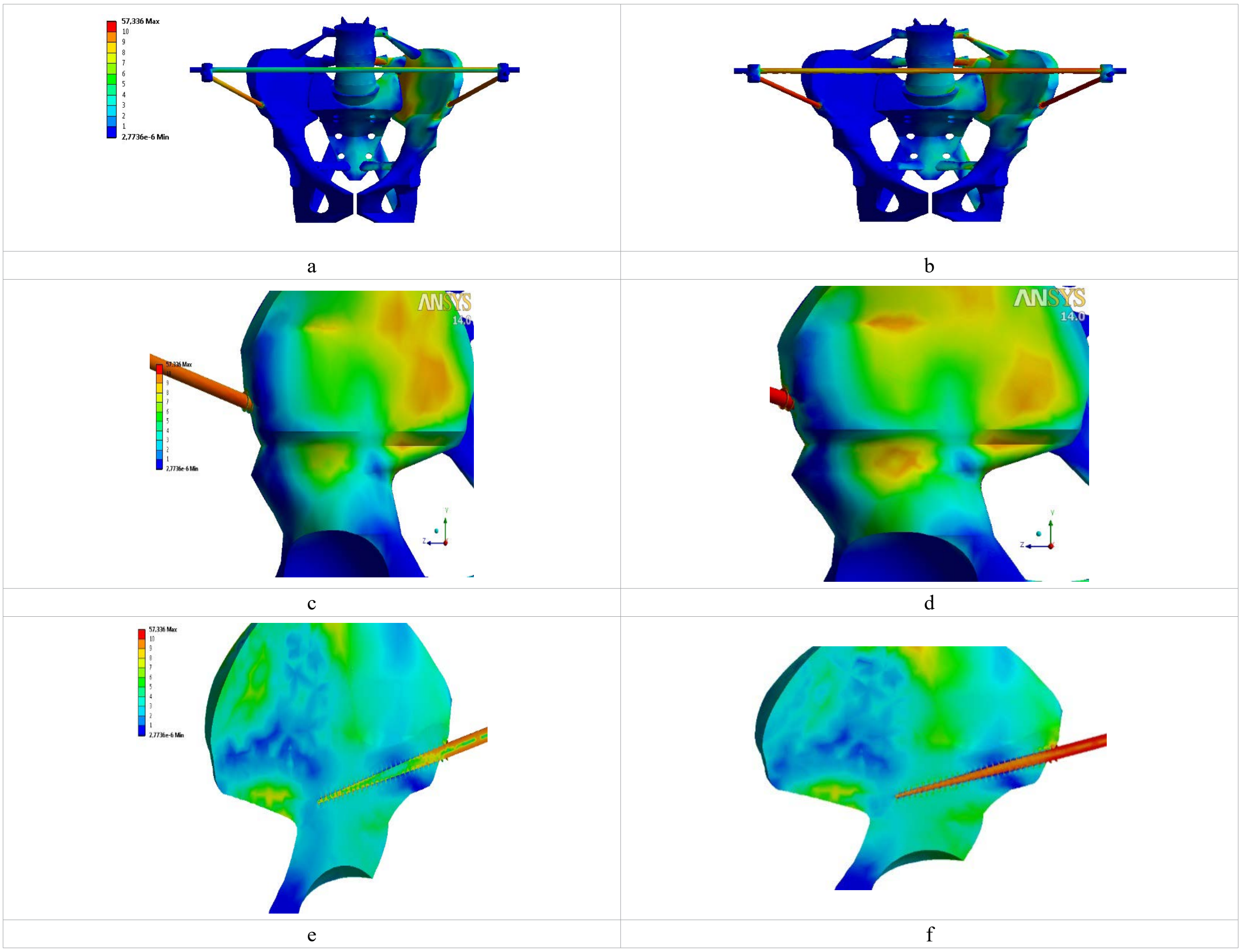


Figure 9. *SSS models of the pelvis with the osteoporotic bone tissue using conical rods of an external fixation device.*

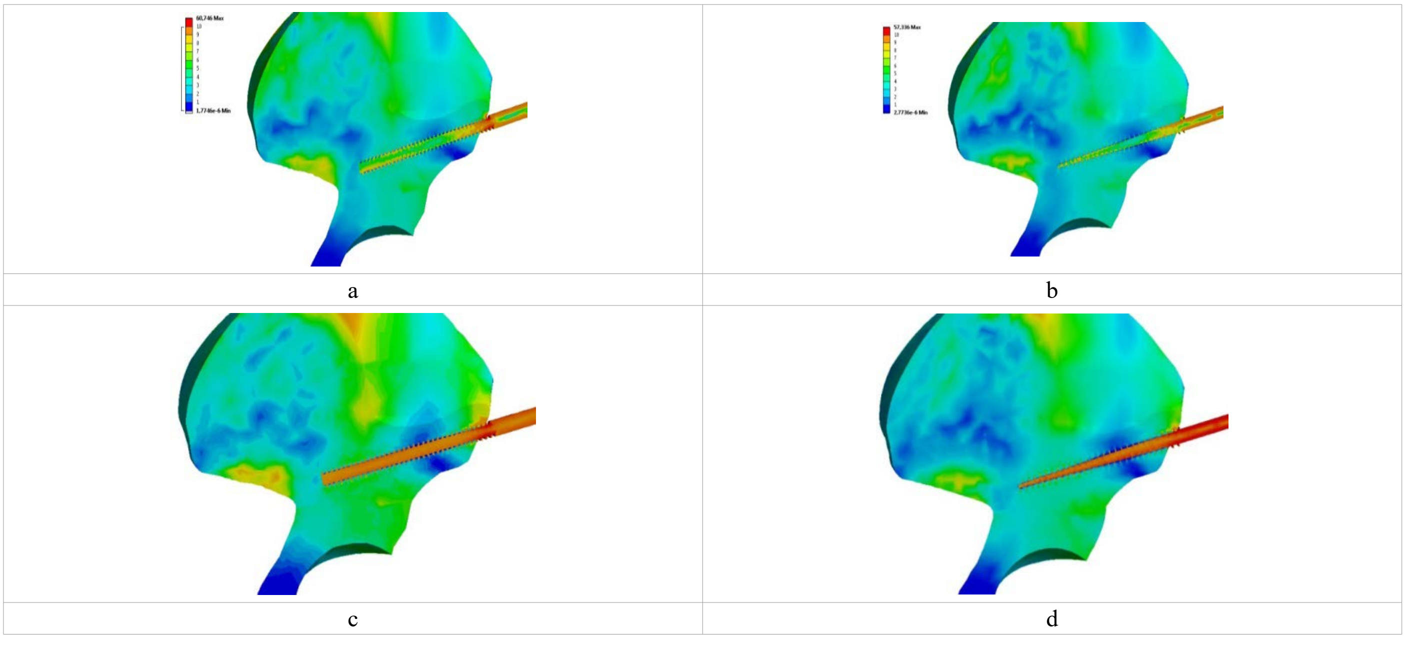


Figure 10. *Comparison of SSS in the iliac section for cylindrical and conical rods in the normal and osteoporotic bone tissue.*

(osteoporosis) allows an assessment of whether bone tissue destruction will occur, especially in areas of stress concentration (such as the nail-bone contact area).The use of conical rods in a device for external fixation of the pelvis makes it possible to reduce the level of SSS both in the area of entry of screws into the bone and in the area of the thinnest part of the iliac ala. For extrafocal pelvic osteosynthesis during polystructure injuries a decrease in the stress state, when conical rods are used, plays an important role since strength characteristics of the osteoporotic bone tissue are significantly lower versus the normal one.

The study showed that stress concentration zones are located at the point where the rods enter the bone and at the place where the rods pass close to the surface of the ilium. The resulting stresses are far from the tensile strength of the metal (the rods will not break), however, destruction may occur in the bone tissue, especially osteoporotic (with a lower tensile strength). The conical shape of the rods forms a smaller channel in the bone tissue, which reduces the stress state in the bone tissue, especially in the area close to the surface of the ilium.

Thus, the use of conical rods in devices for external fixation of the pelvis improves strength characteristics of the "pelvis-rod" system, which makes it possible to recommend their approbation in clinical practice.

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Резюме

МАТЕМАТИЧЕСКОЕ ОБОСНОВАНИЕ ВЫБОРА СТЕРЖНЕЙ ДЛЯ АППАРАТОВ ВНЕШНЕЙ ФИКСАЦИИ ПРИ ПОЛИСТРУКТУРНЫХ ТРАВМАХ ТАЗА.

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С целью биомеханического обоснования экстрафокального остеосинтеза таза при остеопорозе мы изучили напряженно-деформированное состояние (НДС) голени в условиях внешней фиксации аппаратами с цилиндрическими и коническими стержнями.

Материал и методы. Были проведены исследования напряженно-деформированного состояния пояса нижних конечностей методом конечных элементов в условиях внешней фиксации аппаратами со стержнями цилиндрической и конической формы. В методе конечных элементов приближенное решение строится в виде суперпозиции аппроксимирующих функций. На первом этапе решения задачи объект разбивается на области более простой формы - конечные элементы, геометрические размеры которых значительно меньше размеров всей биомеханической системы. Современные программные комплексы выполняют генерацию конечных элементов сетки автоматически используя в большинстве случаев элементы с треугольными гранями. В местах соединения элементов (узловые точки) реальное поле напряжений заменяется действием усилий и перемещениями. Тип конечных элементов характеризуется количеством узлов и степенью аппроксимации неизвестных внутри области и во многом определяет точность получаемого решения в

методе конечных элементов. В проводимых исследованиях учитывались различные виды биологических тканей: компактная и губчатая кость, хрящевая ткань, межпозвоночный диск, связки. В данном исследовании материал считался однородным и изотропным. Основной нагрузкой является вес тела. В расчете вес тела брался равным 700 Н. Геометрическая модель строилась на основе томографических срезов таза, проведенных через 0,5 – 1 см для нерегулярных зон. Моделировался таз с ротационно нестабильным (тип B1 по классификации AO) повреждением после остеосинтеза аппаратом внешней фиксации в вариантах использования стержней цилиндрической и конической формы. Для оценки напряженного состояния использовались напряжения Мизеса. Полученная модель состоит из 75845 конечных элементов и имеет 132253 узла. Построение геометрической модели проводились в программе SolidWorks. Расчеты и анализ НДС проводились в программе ANSYS.

Результаты и обсуждение. В первом варианте исследования модели таза с нормальной костной тканью и цилиндрическими стержнями результаты расчета показали, что при одноопорном стоянии (опора на левую конечность) более напряженной является опорная сторона с выраженными зонами концентрации напряжения в области крестцово-подвздошного сустава, места входа стержня в кость и в области уменьшения толщины крыла подвздошной кости. Вдоль прохождения стержня наблюдаются две зоны концентрации напряжений. Наиболее напряженной является область входа винта в кость (18,5 МПа). Также наблюдается область повышенного напряженного состояния в месте уменьшения толщины крыла подвздошной кости (8,1 МПа), где стержень проходит наиболее близко к кортикальным слоям. Расчет модели с применением стержней конической формы показал, что характер распределения НДС для модели в целом не изменился, а уровень напряженного состояния понизился. Так в месте входа винта в кость величина напряжений Мизеса составляет 16,4 МПа, а в месте уменьшения толщины подвздошной кости – 6,3 МПа. Стоит отметить, что область с повышенным напряженным состоянием вдоль прохождения конического стержня меньше, чем для цилиндрического. Во втором варианте исследования для модели таза с остеопоротической костной тканью сравнительный анализ НДС при использования цилиндрических стержней аппарата внешней фиксации показал, что общий характер распределения напряжений и деформаций для модели в целом не изменился, но уровень НДС повысился. В месте входа винтов в кость он составляет 28,4 МПа, в месте уменьшения толщины крыла подвздошной кости – 9,1 МПа. Уровень напряженного состояния повысился и на всем протяжении контакта «стержень-кость». Сравнительный анализ НДС для варианта конических стержней аппарата внешней фиксации и остеопоротической костной ткани показал, что общий характер распределения НДС для модели в целом не изменился, а уровень напряженно состояния также, как и в модели с цилиндрическими винтами повысился. В месте входа винтов в кость он составляет 26,5 МПа. В месте уменьшения толщины крыла подвздошной кости уровень напряженного состояния – 7 МПа.

Выводы. Использование стержней конической формы в аппарате внешней фиксации таза позволяет снизить уровень напряженно-деформированного состояния как в области входа винтов в кость, так и в зоне наиболее тонкой части крыла подвздошной кости. Для внешнего остеосинтеза таза при полиструктурных травмах понижение напряженного состояния при использовании стержней конической формы играет важную роль, так как прочностные характеристики остеопоротической костной ткани существенно ниже, чем у нормальной. Таким образом, применение конических стержней в аппаратах внешней фиксации таза улучшает прочностные характеристики системы «таз – стержень», что позволяет рекомендовать их апробацию в клинической практике.

Ключевые слова: остеопороз, таз, внешняя фиксация, математическое обоснование, цилиндрический или конический стержень.