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# EXTERNAL AND INTERNAL FIXATORS FOR TREATMENT OF COMPLICATED FRACTURES IN TRAUMATOLOGY AND ORTHOPAEDICS

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**Abstract:** *In this paper, doctors want to draw attention to the possibilities of treatment of complicated fractures of limbs and pelvis. They present their own experiences with the treatment of these fractures by using various types of internal and external fixation. In this paper, engineers report about the new design, testing and numerical modelling of external and internal fixators invented at the VŠB - Technical University of Ostrava and at the Trauma Centre of The University Hospital in Ostrava and at the Pardubice Regional Hospital together with MEDIN a.s. company. These fixators are intended for the treatment of open, unstable, extraarticular or intraarticular and other types of complicated fractures in traumatology and orthopaedics for humans or animals limbs. The new design of external fixators is based on the development of Ilizarov and other techniques (i.e. shape and weight optimization based on composite materials, application of smart materials, nanotechnology, low x-ray absorption, antibacterial protection, patient's comfort, reduction in the duration of the surgical treatment, and cost). Similarly, the new intramedullary nail C-NAIL (i.e. an example of internal fixator) is intended for minimal-invasive fixation of intraarticular calcaneal fractures.*

**Keywords: External and internal fixators, Traumatology, Design, numerical modelling, Experiments, Calcaneal nail.**

## 1. Introduction

Changes in lifestyle, wars in the world, increased age of population, accidents and development of endoprosthetics etc. are connected with increased occurrence of many types of unstable, opened, periprosthetic and other types of complicated fractures in recent years, see Fig. 1 and 2. Every bone fracture leads to a complex tissue injury involving the bone and the surrounding soft parts.

There exist several possibilities of treatment of these fractures, each involving possible complications. For this reason, the complicated fractures are an important therapeutical problem for their individual and

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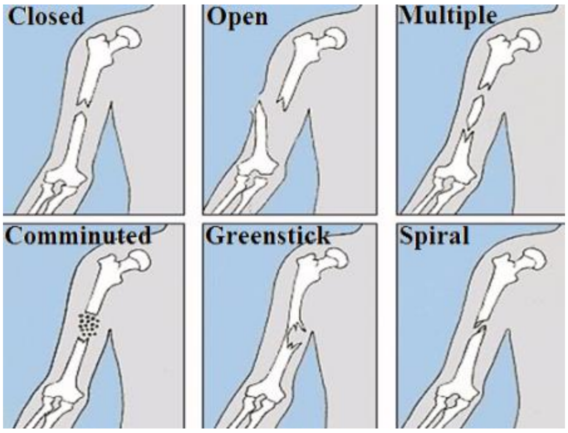
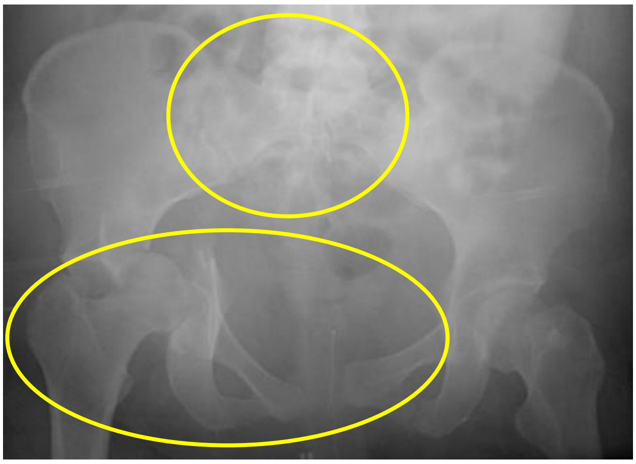
specific character. Among the general risk factors we can include possible infects, osteoporosis, rheumatoid arthritis, treatment with corticosteroids and naturally other diseases which may affect healing processes of patients.




*a)* *b)*

*Fig. 1: a) X-ray Rorabeck type II fracture (periprosthetic) – lateral view; b) Musculoskeletal fractures.*




*a)* *b)*

*Fig. 2: X-ray a) Fracture of pelvis and its acetabulum (anteroposterior radiograph - transverse with posterior wall acetabular fracture), b) X-ray of a depressed calcaneal fracture.*

There is still continuing debate which treatment option is optimal for these patients. There is no consensus on the technique to be used but logically it must be minimally invasive to decrease mortality and morbidity. Stable osteosynthesis obtained by minimal invasive techniques assures more rapid fracture union. Therefore, treatment of fractures is a challenge for the surgeon, see for example Džupa et al (2013), Pleva (1992), Seligson et al (2012), Solomin et al (2012), Stehlík et al (2010) etc.

Usually, there is no consensus on the surgical management of fractures (external fixation versus internal fixation etc.). However, this text is focused on the treatment of complicated fractures solved via external fixation (examples for limbs and pelvis, see Fig. 1 and 2a) and internal fixation (example for calcaneus, see Fig. 2b) and their engineering verification via numerical methods and laboratory testing. Hence, the authors report about their work, development and cooperation between the VŠB - Technical University of Ostrava, the Trauma Centre of The University Hospital in Ostrava, the Pardubice Regional Hospital and MEDIN a.s. company, for example see Frydrýšek1 et al (2011), Frydrýšek2 et al (2011), Frydrýšek et al (2013) and http (2014).

## 2. External Fixators

External fixators can be applied in traumatology, surgery and orthopaedics for treatments such as: open and unstable (complicated) fractures, limb lengthening, deformity correction, consequences of poliomyelitis, foot deformities, hip reconstructions, etc. Hence, external fixators can be used for treatment of humans and animals, for example see Fig. 3 (i.e. one story of a patient treatment in Ostrava), see Frydrýšek et al (2013).

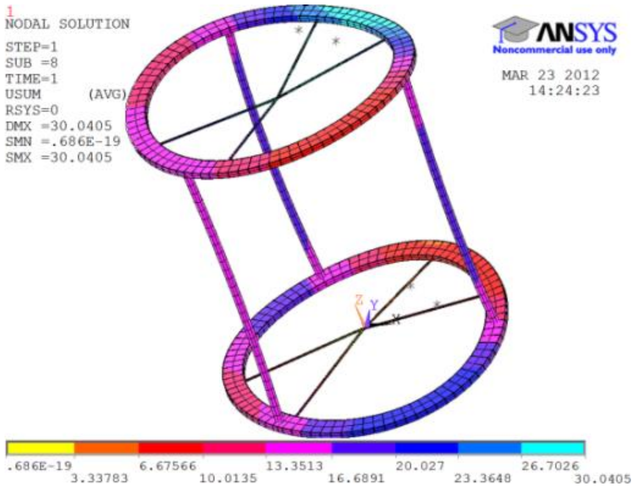
*Fig. 3: Post-operative X-ray snapshot and a patient after the external fixation of periprosthetic fracture above the knee arthroplasty, see reference Frydrýšek et al (2013).*

In references Frydrýšek1 et al (2011) and Frydrýšek2 et al (2011), the way for designing of a new external fixators which satisfy the new trends in medicine is presented (i.e. rtg. invisible of the outer parts of fixators, antibacterial protection, new materials and new design etc.), see Tab. 1.

*Tab. 1 New ways for designing external fixators applied in treatment of open and unstable fractures*

| DEMANDS: | BENEFITS AND EXPLANATION: | GOALS: |
|---|---|---|
| **Outer parts of fixators must be x-ray invisible:** | **Easy to see fracture; reducing radiation exposure for patients and surgeons; shortening the operating time.** | **New smart materials (mostly not metal)** |
| **Antibacterial protection:** | **Application of nanoadditives containing selected metal-based nanoparticles on the surface of the outer parts of the fixators. May allow for growth inhibition of several pathogens and thus prevent or reduce possible infection.** | |
| **Weight optimization, patient's comfort and easy to assembly:** | **To avoid the overloading of limbs fixed by external construction. Reducing the time of the surgical operation and reducing the overall cost. For example, patients usually have better feelings, easier motion and physiotherapy with fixators made up from lighter composites (reinforced plastics) than heavier metals.** | **New design (structure)** |
| **Proper mechanical properties and reliability of structure:** | **Stiffness of fixators, fatigue tests of the whole system, etc. are based on laboratory testing of new smart materials.** | **Numerical modelling (FEM, SBRA Method) and experiments** |

Numerical modelling and laboratory experiments based on the previous skills, see references Frydrýšek1 et al (2011), Frydrýšek2 et al (2011) and Frydrýšek et al (2013), as support for research and design, are very important parts of the solution, see Fig. 4 (i.e. applications of FEM and experiments – fixator for fractures of limbs) and Fig. 5 (i.e. applications of FEM – fixator for fractures of pelvis and its acetabulum).




*a)*

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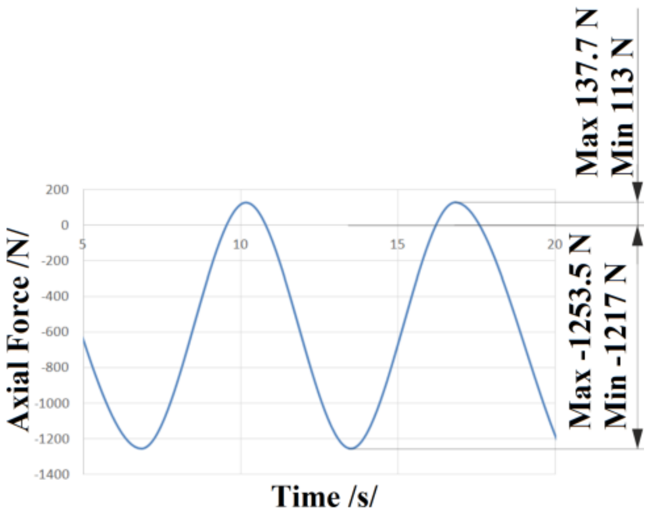
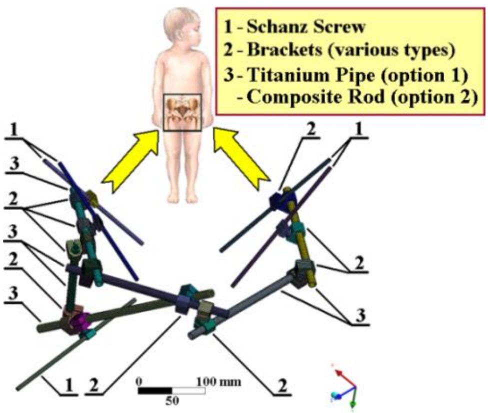



*d)*

*Fig. 4: External fixator for limbs a) FEM – total displacements in the structure; b) Experiments in our laboratory (quasi-static cyclic overloading by axial force); c) Experiments in our laboratory (force transducer d) Experiments in our laboratory (quasi-static cyclic overloading by axial force, external fixators for the limbs).*

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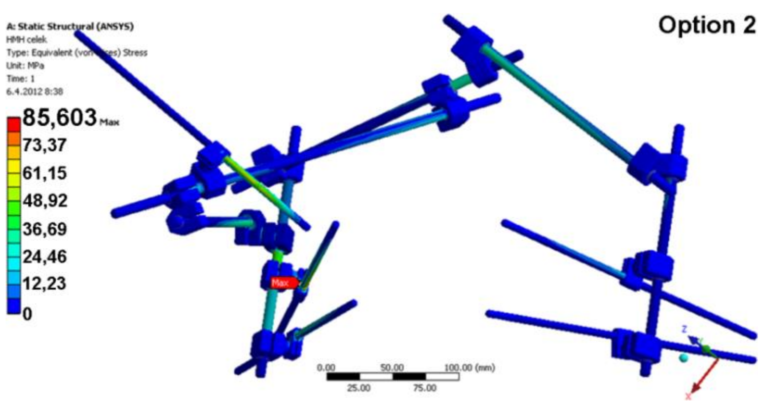


*b)*

*Fig. 5: External fixator for treatment of pelvis and its acetabulum a) design and application; b) FE modelling - equivalent stresses.*

According to the laboratory experiments (i.e. preclinical research) and numerical modelling (strength analyses), the verifications of external fixators for limbs and pelvis and its acetabulum are sufficient.

Therefore, these are reliable and can be used for treatment of patients. For more information see Frydrýšek1 et al (2011), Frydrýšek2 et al (2011), Frydrýšek et al (2013) and Tab. 2.

*Tab. 2 Example of evaluation - results comparing external fixators for the pelvis and its acetabulum (designs "Option 1" and "Option 2").*

| **Attributes:** | **Option 1:** | **Option 2:** |
|---|---|---|
| **Design:** | ⊖ **old** | ⊕ **new** |
| **Material:** | ⊖ **titanium, stainless steel** | ⊕ **carbon fibre, titanium, stainless steel** |
| **Added antibacterial protection:** | ⊖ **no** | ⊕ **yes** |
| **X-ray invisible:** | ⊖ **no** | ⊕ **partly yes** |
| **Weight of external fixator** | ⊖ | ⊕ **decreasing** |
| **Stiffness of external fixator:** | ⊖ | ⊕ **increasing** |
| **Maximum von Mises stresses /MPa/:** | ⊖ **97.1** | ⊕ **85.6 – decreasing; see Fig. 5b** |
| **Maximum total deformation /mm/:** | ⊖ **5.74** | ⊕ **4.32 - decreasing** |
| **Patient comfort:** | ⊖ | ⊕ **improvement** |
| **Reliability assessment** | ⊖ | ⊕ **improvement** |
| **Easy to assemble:** | **the same** | |

## 3. Internal Fixators

Internal fixation is an operation in orthopaedics and traumatology that involves the surgical implementation of implants for the purpose of repairing a bone. Usually, an internal fixator may be made of stainless steel or titanium. Types of internal fixators include bone screws and metal plates, pins, rods, Kirschner wires and intramedullary devices such as the Kuntscher nail and interlocking nail etc.

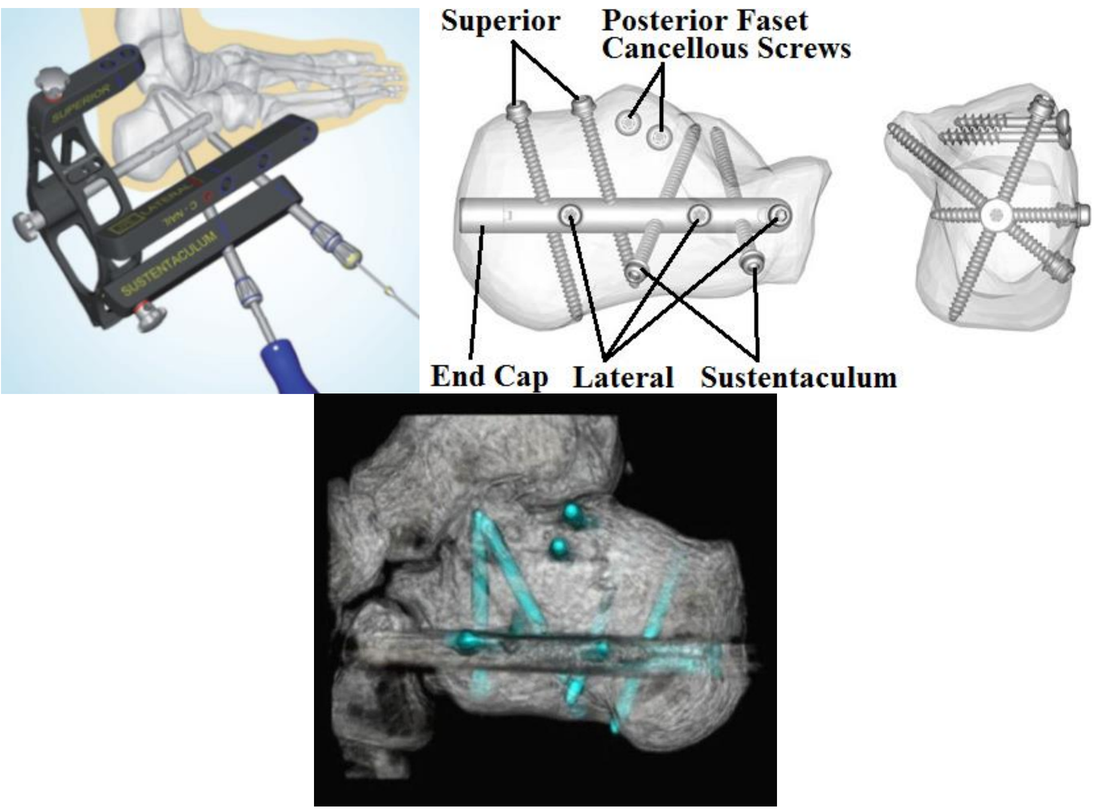


*Fig. 6: C-NAIL and its application.*

This chapter is focused mainly on the C-NAIL, see Fig. 6 and reference http (2014), i.e. the intramedullary nail for minimal-invasive fixation of intraarticular calcaneal fractures. The principle is to stabilize with the nail the four to five main fragments of the fractured calcaneus in conjunction with up to seven interlocking screws and thus creating angular stable fixation. The maximum of stability is achieved by fixing the sustentacular fragment towards the nail with two interlocking screws guided by a very precise aiming device.

Numerical modelling for the C-NAIL rested in a broken calcaneus was performed, see Fig. 7 (i.e. applications of FEM – strength analyses).

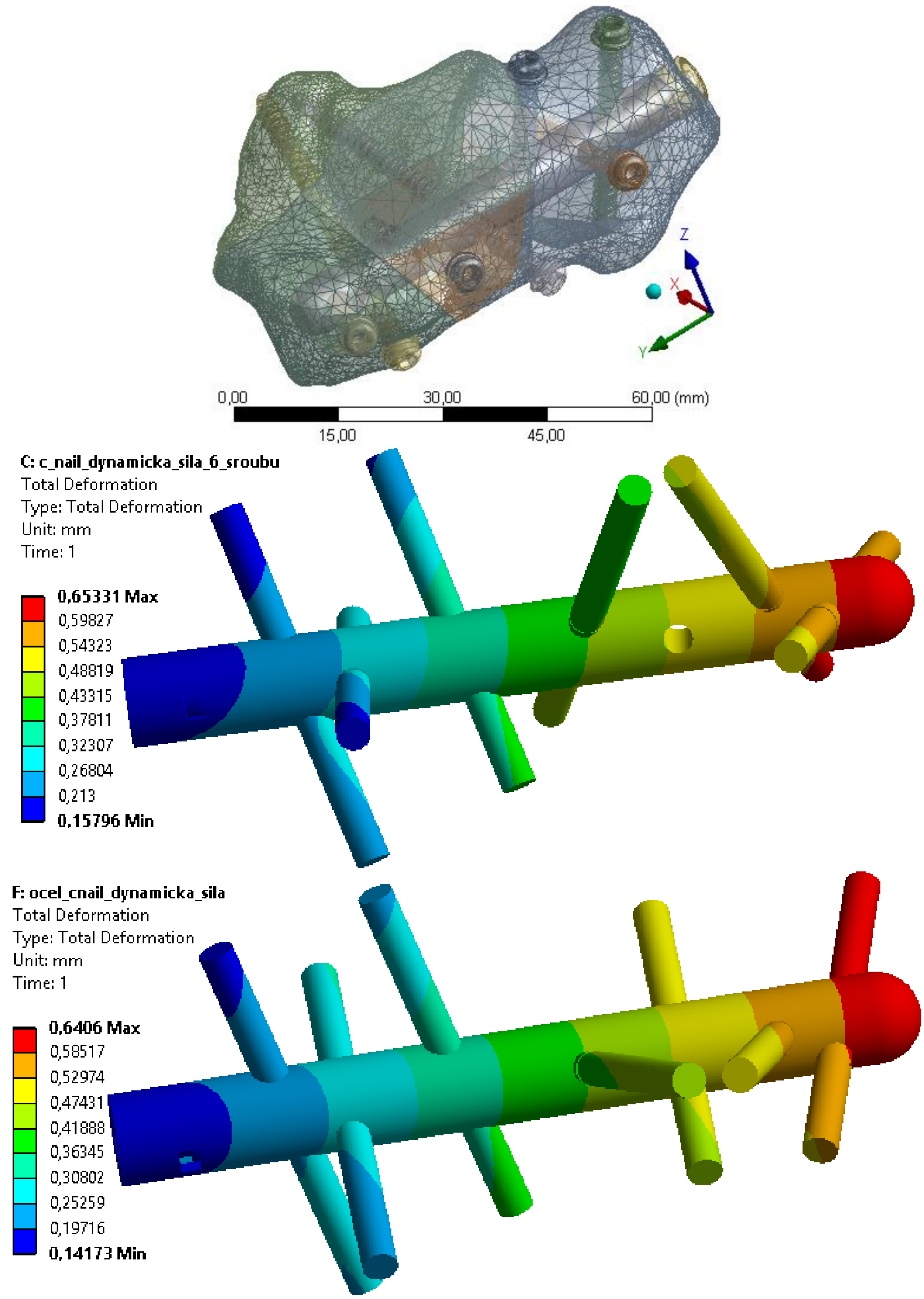


*Fig. 7: C-NAIL (FE model of a broken calcaneus and acquired displacements for dynamic overloading – solution with 7 and 6 screws).*

This is our first, but important, mention about our C-NAIL modelling. So far, in the world, there are not any numerical solutions (stress and displacement assessment etc.) for any type of intramedullary calcaneal nail.

## 4. Conclusion

Complicated fractures represent an important therapeutic problem due to their specific and individual character.

According to the results and applications presented in this paper (i.e. some examples of external and internal fixators for the treatment of limbs, the pelvis and its acetabulum and the calcaneus), the verifications of these fixators are sufficient. Therefore, these fixators can be used for treatment of patients.

This paper has reported on new ways of designing external and internal fixators, based on the results of previous research. The new designs and materials of fixators will satisfy the ambitious demands of modern traumatology, surgery and economics. According to the results, the improvements in the design of fixators for the treatment of fractures are evident. The VŠB – Technical University of Ostrava, together with the University Hospital of Ostrava and the Pardubice Regional Hospital, are cooperating with the Czech company MEDIN a.s. (Nové Město na Moravě, Czech Republic). Therefore, not all results could be published in this paper due to reasons of confidentiality.

**This is our first and original information about our C-NAIL modelling. Application of C-NAIL is a new and innovative trend in mini-invasive traumatology and orthopaedics. C-NAIL is a good alternative for older and typical treatments performed via calcaneal plating systems.**

Our team is dealing with other types of fixation too. Such as femoral neck fractures treated via femoral screws (analytical, numerical and probabilistic approach), for more information see Fig. 8 and Frydrýšek1 (2014) and Frydrýšek2 (2014).

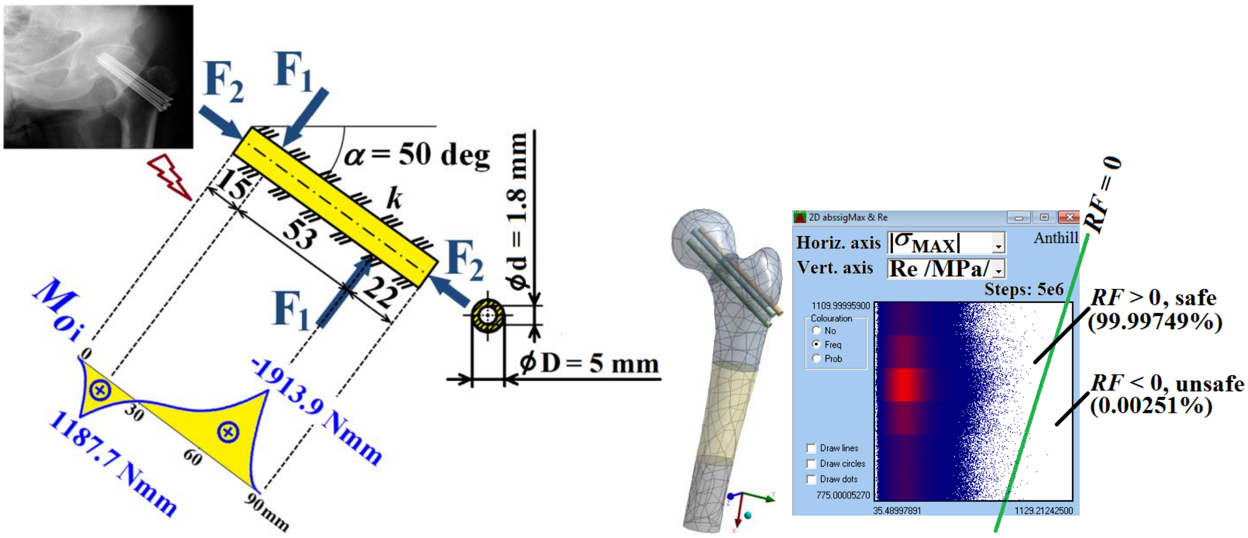


*Fig. 8: Cannulated femoral screws (stress evaluation via analytical, numerical and probabilistic approach).*

### Acknowledgement

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