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# NEW DESIGNS OF EXTERNAL FIXATORS FOR TREATMENT IN TRAUMATOLOGY

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**Abstract:** *This paper reports about the new design of external fixators invented at the VŠB - Technical University of Ostrava and at the Trauma Centre of The University Hospital in Ostrava together with MEDIN a.s. company. These fixators are intended for the treatment of open, unstable and complicated fractures in traumatology and orthopaedics for humans or animals. The new design is based on the development of Ilizarov and other techniques (i.e. shape and weight optimalization 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).*

**Keywords:** ***biomechanics, traumatology, design, experiments, numerical modelling***

## 1. Introduction

According to current studies and research, performed at VŠB – Technical University of Ostrava and Traumatology Centre of the University Hospital of Ostrava (Ostrava, Czech Republic) and Trauma Hospital of Brno (Brno, Czech Republic), for examples see references Pleva (1999), Podešva (2002), Stacha (2005), Rozum (2008), Pokorný & Paša et all (2007), Janečka (2011), Frydrýšek et all (2011), Frydrýšek (2012) and mentioned web page, the current design of external fixators can be modified, see Fig. 1. 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.

External fixation, see Fig. 1, is a surgical treatment usually used to set bone fractures in which a cast (plaster) would not allow proper alignment of the fracture. In this kind of reduction, holes are drilled into uninjured areas of bones around the fracture and special bolts or wires are screwed into the holes. Outside the body, rods and curved pieces of metal with special joints connect the bolts to make a stiff support. The complicated fracture can be set in the proper anatomical configuration. Since the bolts pierce the skin, proper cleaning to prevent infection at the site of surgery must be performed. External fixation is usually used when internal fixation is contraindicated, or as a temporary solution. During its use, it is also possible to use and exercise the broken limbs and even walk.

However, a modern design of these fixators is needed to satisfy new trends in medicine, see the following text.

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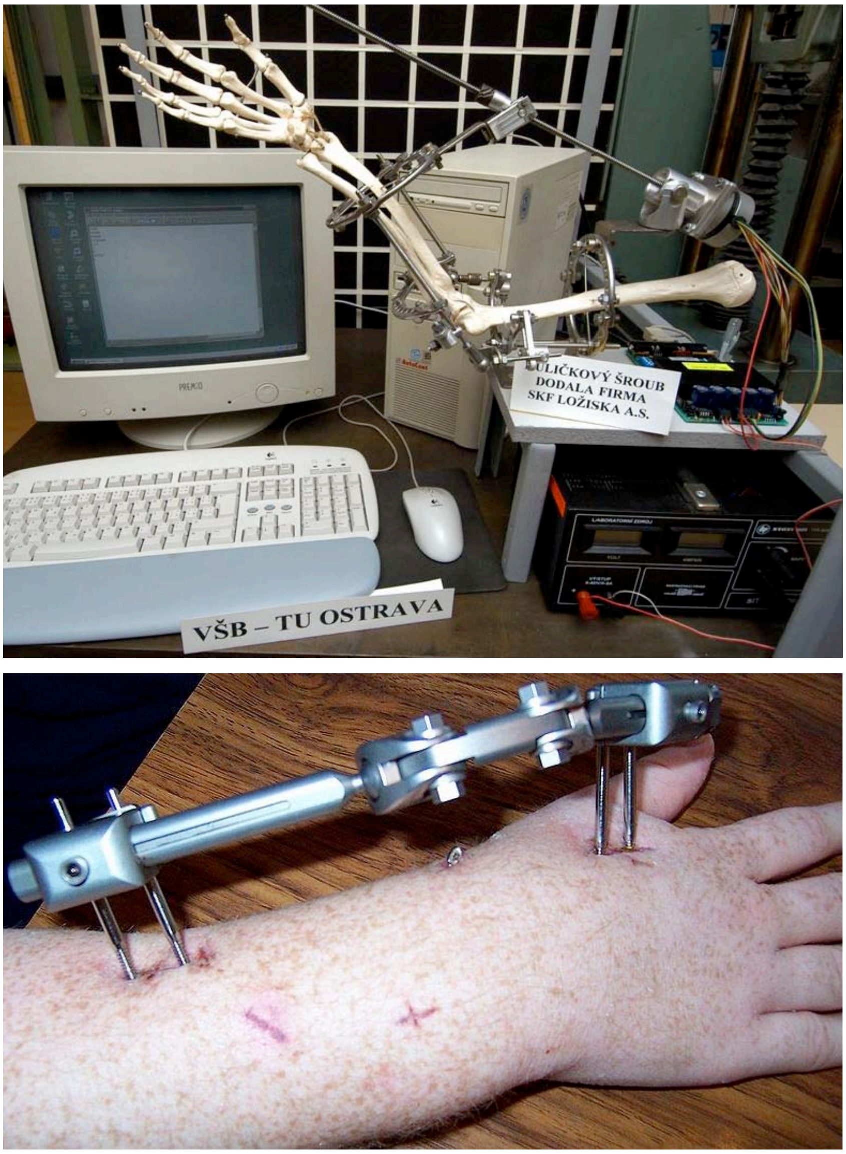


*Fig. 1: Current design of external fixators*

## 2. New Ways for Designing External Fixators

Scientific and technical developments, together with medical care and medical practice, bring new demands for designs of external fixators. These demands should be solved by: applications of new smart materials, new design, measuring of the real loadings and numerical modelling and experiments. These points are mutually connected.

**Applications of new smart materials** should satisfy the following requirements:

**a) Low X-ray absorption** (i.e. X-ray invisible) for the outer parts of fixators, see Fig. 2. The outer parts of fixators are usually made of metal (titanium, duralumin, stainless steel), which are visible in X-ray diagnostic. Sometimes, the surgeons must repeat X-ray diagnostics (from different points of view) during the operation, because it is difficult to see the broken limbs. Therefore, it is important to make the outer parts X-ray invisible, which leads to shortening the operating time and reducing radiation exposure for patients and surgeons.

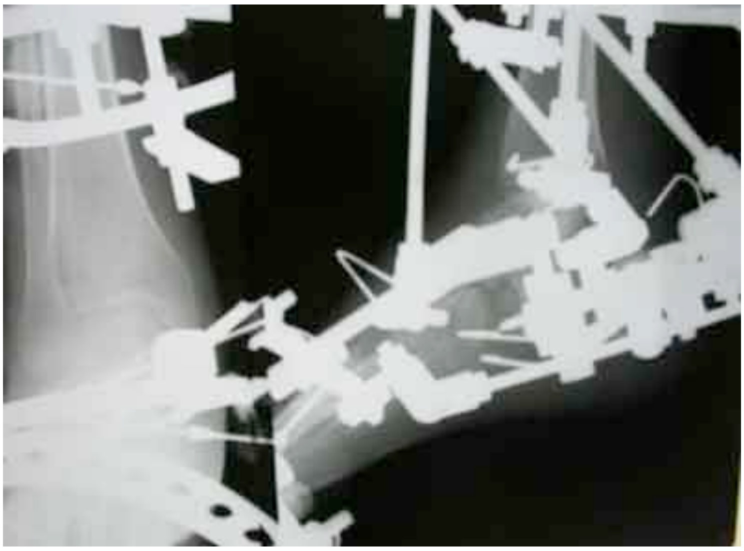

*Fig. 2: Problems with high X-ray absorption (it is difficult to see broken limbs because there is too so much metal parts)*

**b) 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 present on human skin and thus prevent or reduce possible infection. Nanotechnology allows a built-in antibacterial protection for solid products, coatings and fibres. Antibacterial protection gives products an added level of protection against damaging microbes such as, bacteria, mould and mildew that can cause cross-contamination and product deterioration. Antibacterial nanotechnology, combined with regular cleaning practices, helps to improve hygiene standards and provides extra protection wherever it is used. For more information see references Tokarský et all (2009), Valášková et all (2009) and Frydrýšek et all (2011).

**c) Proper mechanical properties** (stiffness of the whole system of fixators, fatigue testing, etc.) is based on laboratory testing of new smart materials.

**d) Weight optimalization** - to avoid the overloading of limbs fixed by external construction. This is based on the application of numerical methods and experiments.

It is possible to satisfy all these demands with a new material which uses proper plastics (polymers), because some current solutions based on light metals (aluminium, titanium etc.) are visible in X-ray diagnostic, see Fig. 2 and 3.

*Fig. 3: Design of external fixators a) Based on metals (current design, heavier, expensive, etc.) b) Based on reinforced polymers (new design, lighter, cheap, more friendly etc.)*

A **new design** should be made according to shape, ecological perspective, a patient's comfort, reducing the time of the surgical operation and reducing the overall cost. Technical aesthetics of fixators also have impacts on the psyche of the patients (i.e. "friendly-looking design of fixators"). For example, patients usually have better feelings, easier motion and physiotherapy with fixators made up from lighter composites (reinforced plastics) than heavier metals, see Fig. 3. In addition, polymers are easy recycled.

During the patient's treatment is important to do **measurements of the real loadings and stiffness of the external fixators** (laboratory measurement and measurement in vivo - painlessly) and data processing are needed. The original type of measuring is very important for future possible enhancements. This is based on strain gauge measurement and applied statistics and the Simulation-Based Reliability Assessment (SBRA) Method, see references Marek et all (2003), Frydrýšek (2010), Kala (2011), Frydrýšek (2012) and Fig. 4. This type of measuring and processing in vivo has never been applied before to the solution of problems of external fixators. This new solution promises new (so far not investigated) information about real loadings of external fixators during the treatments of patients. In a structural reliability assessment the concept of a limit state separating a multidimensional domain of random (stochastic) variables into "safe" and "unsafe" domains has been generally accepted and is increasingly used in structural reliability theory and in design applications.

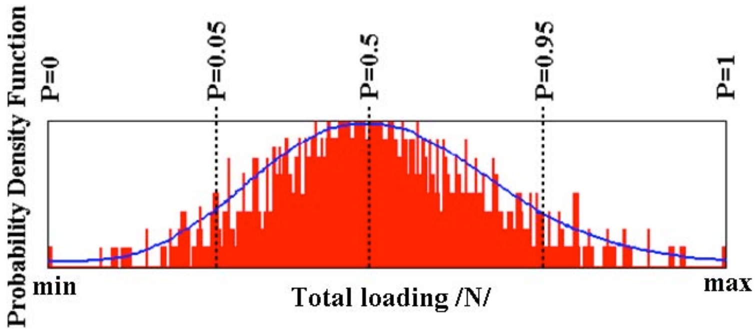


*Fig. 4: Typical loading spectrum of an external fixator (overloading is included)*

**Numerical modelling and experiments** (based on the previous skills, see references Pleva (1999), Podešva (2002), Stacha (2005), Pokorný & Paša et all (2007), Rozum (2008), Frydrýšek (2010), Frydrýšek et all (2011), Janečka (2011) and Frydrýšek (2012), as support for research and design, are a very important part of the solution, see Fig. 5, 6, 7 and 8 (i.e. application of FEM and experiments – fixator for fractures of pelvis and its acetabulum) and Fig. 9 (i.e. applications of FEM – fixator for fractures of limbs).

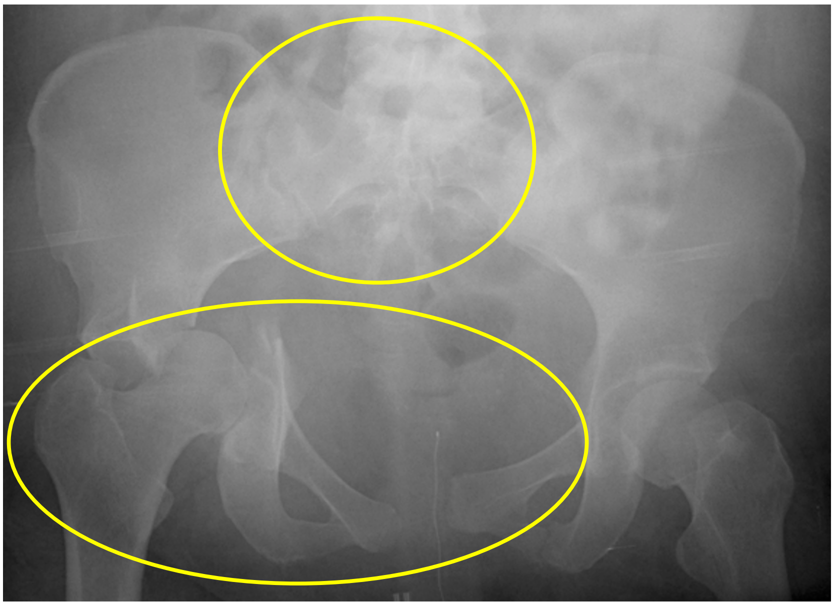

*Fig. 5: Fracture of pelvis and acetabulum and its treatment (anteroposterior radiograph - transverse with posterior wall acetabular fracture).*

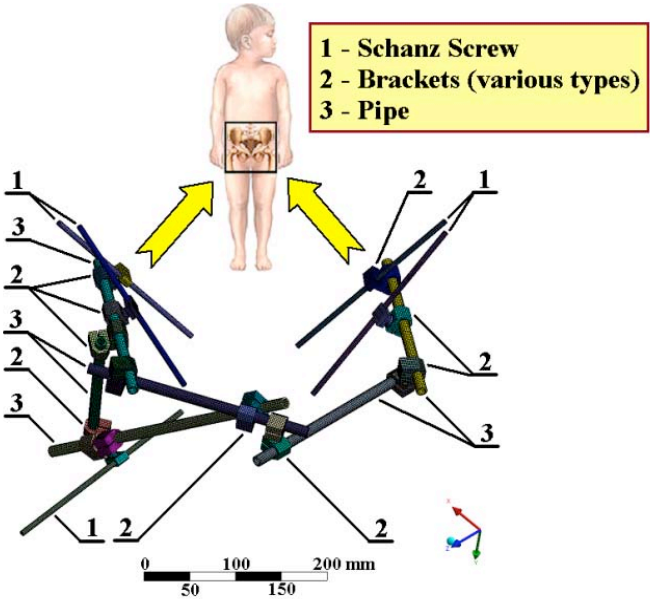


*Fig. 6: Application of the external fixator for treatment of pelvis and its acetabulum*

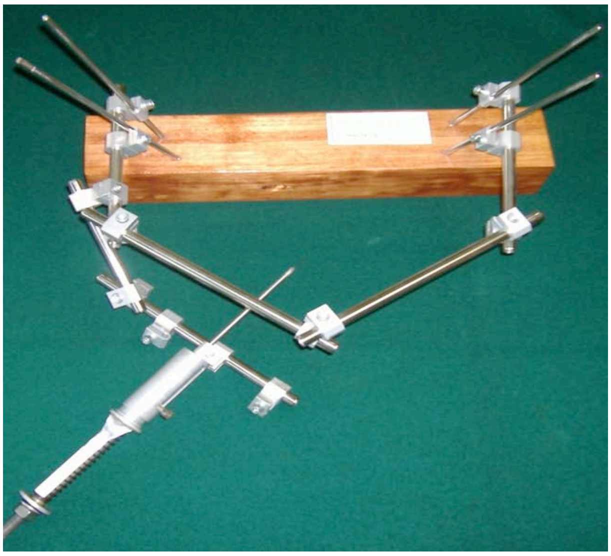

*Fig. 7: Prototype of the external fixator for pelvis and acetabulum and its measurement*

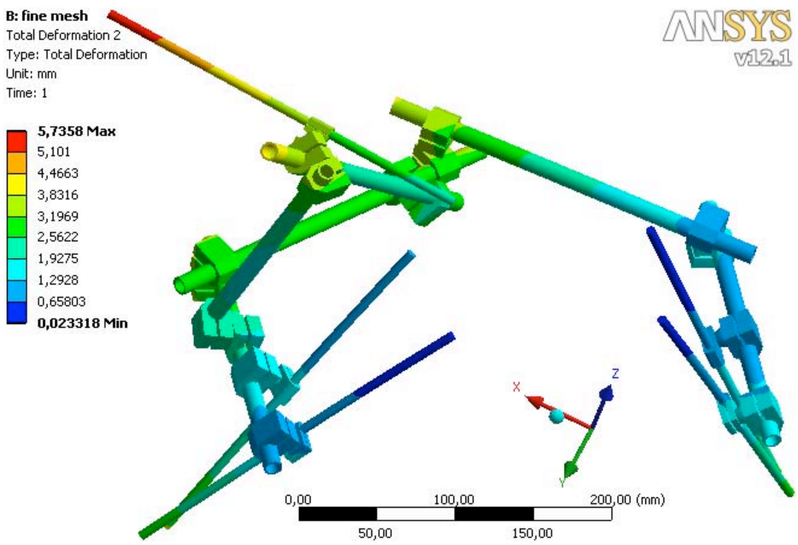


*Fig. 8: FE modelling of external fixator for pelvis and acetabulum (total displacement for tensile loading 100 N).*

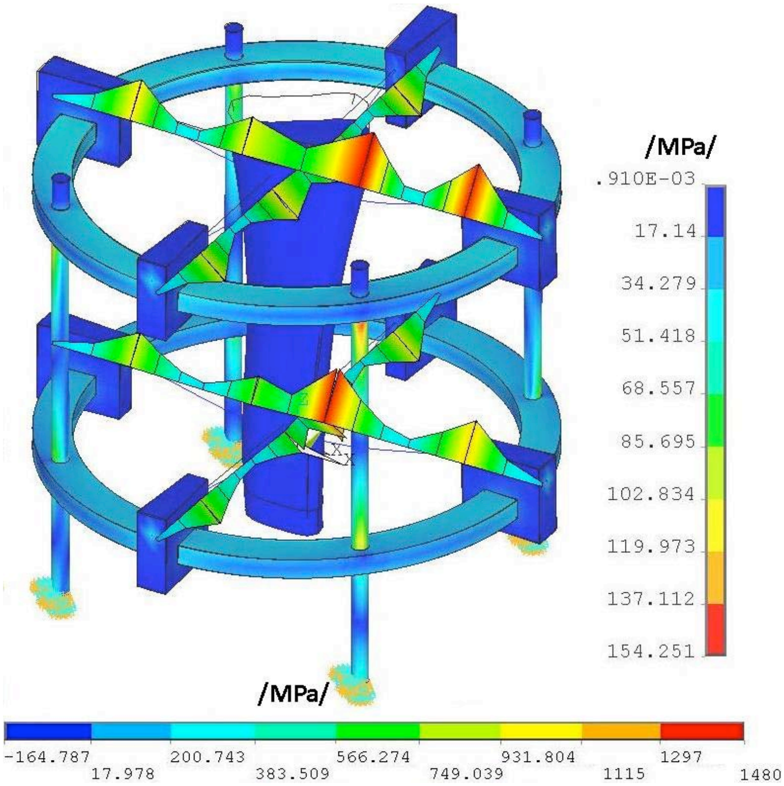


*Fig. 9: FE modelling of external fixator for limbs (Equivalent von Mises stress distribution).*

It is also important to focus on a **new design of rehabilitation aids connected with the new design of external fixators** presented in the former text.

Therefore, we are in the process of proposing the new continuous passive motion system based on the development of the first model, see Fig. 1a (i.e an electronically controled electro-mechanical device, fully programmable with LCD display, lower limb flexion mobilization unit, a noiseless torque gear motor with seat conveyer for excellent flexion angle setting). This new machine can be used for problems of septic arthritis, ligament tendon healing, for the treatment of intra-artricular fractures etc. The machine has a provision for treatment time, setting of flexion angle and extension provision, hold on flexion and hold on extension cyclic time. The machine also can be used for improvement of blood circulation, reduction of venous engorgement of deep venous thrombosis, extra and intra adhesions, joint stiffness and pain reduction etc.

The whole device consists of (can be formed by) the following elements:

- External fixator of any type.
- Special hinge system connecting both the parts of the external fixator in the place of the elbow and enabling both the parts of the fixator to move.
- Two demountable brackets fixed in particular parts of the external fixator.
- Motor driving unit with accessory equipment mounted between the two brackets producing the movement of both the parts of the fixator.
- Electronic control unit of the fixator motor drive.

Main engineering characteristics:

- Output of the drive 50 W
- Supply voltage 12 – 24V
- Current input up to 5 A
- Max. time of extremity bend by 90 - 20 s

Possible a variant of the small power unit:

- External – linear actuators
- Microstepping Driver R356 (see Fig. 10)


*Fig. 10: Possible a variant of the small power unit.*

The external fixator of the elbow joint with a motor drive mechanism and the hinge system will enable the timely rehabilitation of the elbow and will prevent late functional limitations that are the most serious complications at using the existing methods of healing limb fractures by external fixators, and that in many cases, result in the arthrodesis of the elbow joint.

## 3. Conclusions

Report about the new ways to design of external fixators, based on the results of previous research, was presented. Hence, the new designs and materials of fixators will satisfy the ambitious demands of modern traumatology, surgery and economics.

VŠB - Technical University of Ostrava (Faculty of Mechanical Engineering, Faculty of Metalurgy and Material Engineering, Faculty of Electrical Engineering and Computer Science and Centre of Nanotechnology) together with University Hospital of Ostrava and Trauma Hospital of Brno are now in the middle of a process creating a new design for external fixators. Hence, they are in cooperation with the Czech producers MEDIN (Nové Město na Moravě, Czech Republic) and ProSpon (Kladno, Czech Republic).

The new proposed designs cannot be more specifically described here, for confidentiality reasons.

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