REPORT ABOUT THE NEW EXTERNAL FIXATORS FOR TREATMENT OF COMPLICATED LIMB FRACTURES

Assoc. Prof. M.Sc. Karel FRYDRÝŠEK, Ph.D., ING-PAED IGIP 1)
Assoc. Prof. M.Sc. Leopold PLEVA, Ph.D. 2)
M.Sc. Oldřich UČEŇ, Ph.D. 1)
M.Sc. Tomáš KUBÍN, Ph.D. 1)
M.Sc. Jaroslav ROJÍČEK, Ph.D. 1)
M.D. Milan ŠÍR 2)
M.D. Roman MADEJA 2)

1) Department of Mechanics of Materials & Department of Production Machines and Design
Faculty of Mechanical Engineering
VŠB – Technical University of Ostrava
17. listopadu 15/2172, 708 33 Ostrava, Czech Republic
e-mail: karel.frydrysek@vsb.cz, oldrich.ucen@vsb.cz, tomas.kubin@vsb.cz, jaroslav.rojicek@vsb.cz

2) Trauma Centre
University Hospital in Ostrava,
17. listopadu 1790, 708 52, Ostrava, Czech Republic
e-mail: leopold.pleva@fnspo.cz, milan.sir@fnspo.cz, roman.madeja@fnspo.cz

Abstract: - This article 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. and ProSpon s.r.o. companies. These fixators are intended for the treatment of open, unstable and complicated fractures in traumatology and orthopaedics for humans or animals limbs. The new design 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).

Key-Words: - biomechanics, traumatology, design, experiments, numerical modelling, external fixators, fractures, limbs

1 Introduction
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.1 and example (i.e. one story) of patient treatment Fig.2, 3 and 4.

According to current studies and research, performed at VŠB – Technical University of Ostrava, Trauma Centre of the University Hospital of Ostrava (Ostrava, Czech Republic) and Trauma Hospital of Brno (Brno, Czech Republic), together with MEDIN a.s. and ProSpon s.r.o. companies, for examples see references [2], [4], [5], [6] and [8], the current design of external fixators can be modified.

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.

Fig. 1 a) Example of open and complicated fracture (human), b) Application of external fixator (treatment of dog) – source internet.
needed to satisfy new trends in medicine. Hence, this paper reports about the designing of external fixators intended for treatment of open and complicated fractures of limbs.

2 New Demands 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:

1. Applications of new smart materials, see chapter 2.1.
2. New design, see chapter 2.2.
3. Measuring of the real loadings, see chapter 2.3.
4. Numerical modelling and experiments, see chapter 2.4.

These points which are mutually connected are discussed in the following subchapters.

2.1 Applications of new smart materials

a) Low X-ray absorption (i.e. rtg. invisible) for the outer parts of fixators, see Fig.5. 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.

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 [2] and [7].

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

d) Weight optimization - 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.5 and 6.
Fig. 6 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.).

2.2 New design
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.6. In addition, polymers are easy recycled.

2.3 Measurements of the real loadings and stiffness of the external fixators
During the patient’s treatment, it 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 [1], [3] and Fig.7. 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.

2.4 Numerical modelling and experiments
Numerical modelling and experiments (based on the previous skills, see references [2], [4], [5], [6] and [8], as support for research and design, are a very important part of the solution, see Fig.8 to 12 (i.e. applications of FEM and experiments – fixator for fractures of limbs).

Fig. 8 Experimental measurements.

Fig. 9 Numerical modelling (FEM – equivalent von Mises stresses in the structures).

Fig. 10 Numerical modelling (FEM – total displacements in the structure).
3 Conclusion

The results of experiments fit quite well with numerical modelling. According to the results, the improvements in the designing of external fixators for treatment of limb fractures are evident.

Report about the new ways to design of external fixator, 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 together with University Hospital of Ostrava and Trauma Hospital of Brno are now in the middle of a process creating new designs for external fixators. Hence, they are in cooperation with the Czech producers MEDIN Nové Město na Moravě (Czech Republic) and ProSpon Kladno (Czech Republic). Therefore, all results could not be published in this paper due to confidentiality reasons.

The work has been supported by the grant projects MPO FR-TI3/818 (sponsored by Ministry of Industry and Trade of the Czech Republic) and 7AMB12SK126 (sponsored by The Ministry of Education, Youth and Sports of the Czech Republic).

References:


