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Verification of External Fixators Applied in Traumatology and Orthopaedics

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Abstract. In this paper, the authors draw attention to biomechanics connected with the possibilities of treatment of complicated bone fractures. They present information about their own design, laboratory tests and numerical solutions (i.e. strength analyses and reliability assessments) of the various types of external fixators applied in traumatology and orthopaedics (i.e. intended for fractures of limbs and pelvis and its acetabulum). The new design of external fixators is based on the development of Ilizarov and other techniques and satisfies new demands of science.

Introduction

Changes in lifestyle, military conflicts, increased population age, accidents, the development of endoprosthetics etc. are connected with the increased occurrence of many types complicated bone fractures in recent years; see Fig. 1. There exist several possibilities for treatment of these fractures, each involving possible complications.

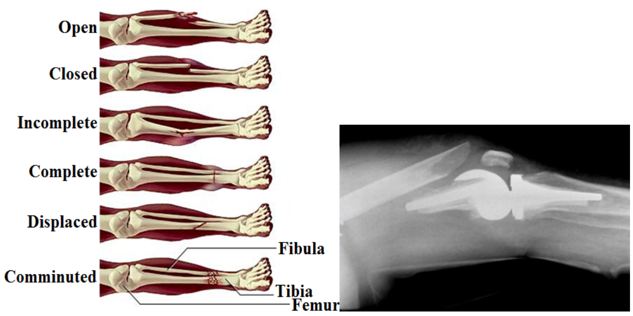

Fig. 1. a) Types of fractures; b) X-ray snapshot of Rorabeck type II fracture (periprosthetic, lateral view).

For this reason, complicated fractures represent an important therapeutic problem due to their specific and individual character. Among the general risk factors we can include possible infections, osteoporosis, rheumatoid arthritis, treatment with corticosteroids, and naturally other diseases which may affect healing processes in patients. There is no consensus on the optimal technique to be used for treatment, but logically it must be minimally invasive in order to decrease mortality and morbidity.

This text focuses on the treatment of complicated fractures treated via external fixation, see Fig. 2, and their engineering verification. External fixators can be applied in traumatology and orthopaedics for treatments such as complicated fractures, limb lengthening, deformity correction, consequences of poliomyelitis, foot deformities or hip reconstructions for humans and animals. These fixators must be in line with new trends in medicine, see Table 1.

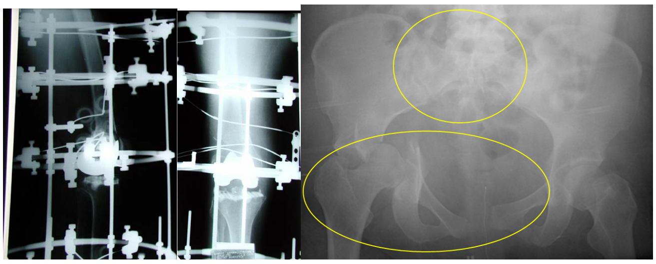

Fig. 2. a) Post-operative X-ray snapshot of a patient after the external fixation of a periprosthetic fracture following above the knee arthroplasty; b) Fracture of the pelvis and its acetabulum (anteroposterior radiograph - transverse with posterior wall acetabular fracture).

Table 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 and experiments**

In order to increase the antibacterial potency of external fixators, kaolinite/nanoTiO2 composite was laboratory prepared and its antibacterial activity tested with respect to daylight irradiation time. X-ray powder diffraction, Raman and FTIR spectroscopic methods revealed titanium dioxide only in the form of anatase in all evaluated samples (non-calcined and calcined) and also transformation of kaolinite to metakaolinite after the calcination treatment. A standard microdilution test was used to determine the antibacterial activity using four human pathogenic bacterial strains (Staphylococcus aureus, Escherichia coli, Enterococcus faecalis, and Pseudomonas aeruginosa). The antibacterial assays found all the samples to have antibacterial potency with different onset of the activity; calcined samples exhibited antibacterial activity earlier than non-calcined samples. No significant difference in antibacterial activity of the samples for different bacterial strains was observed. For more information see [1] to [8].

External Fixators for Treatment of Pelvis and its Acetabulum

At the VŠB – Technical University of Ostrava, 6 designs of external fixators (fully metallic or partly metallic - there are composite rods made of carbon fibres which are X-ray invisible etc.) intended for treatment of pelvis and acetabulum fractures were designed; for example see Fig. 3 and references [2] and [3].

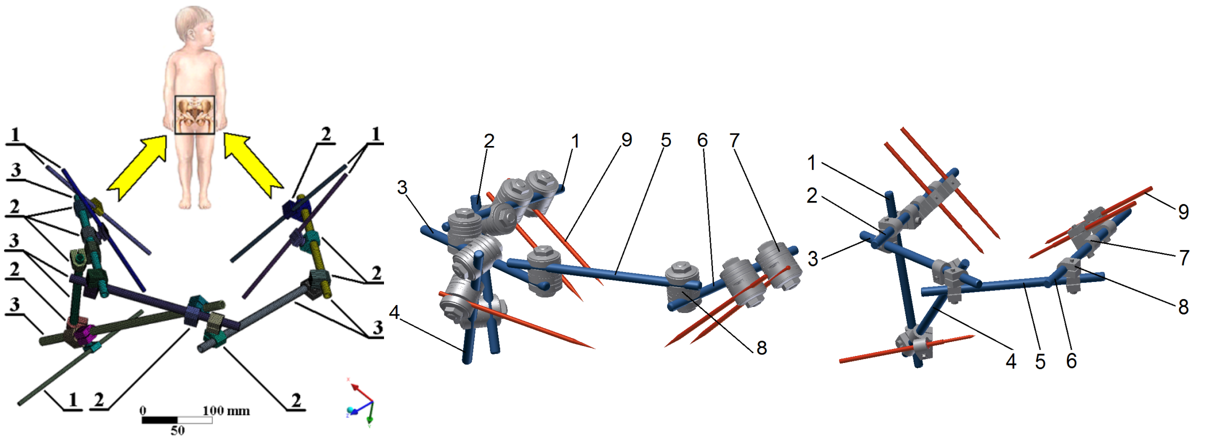

Fig. 3. Application of external fixators for treatment of the pelvis and its acetabulum.

These fixators were tested in the laboratory and numerically modelled via FEM, see Fig. 4. The works were focused mainly on the stiffness and reliability of the whole systems and its interaction with the pelvis (i.e. measurements at particular points – pulling the hip bone outwards from the acetabulum after the repositioning of pelvis fragments).

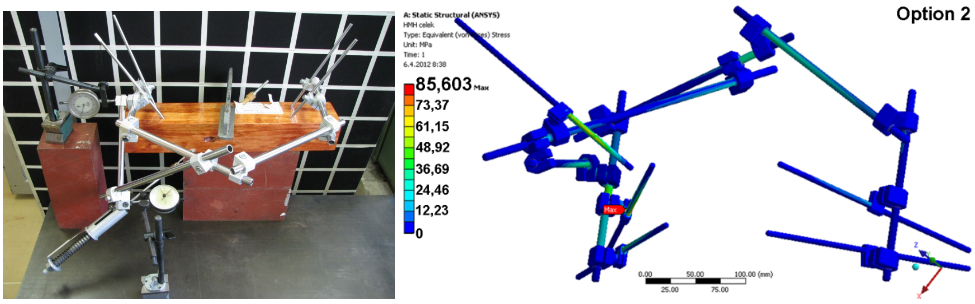

Fig. 4. External fixator for the pelvis and acetabulum a) stiffness measurement; b) FE modelling (equivalent von Mises Stress).

External Fixators for Treatment of Limbs

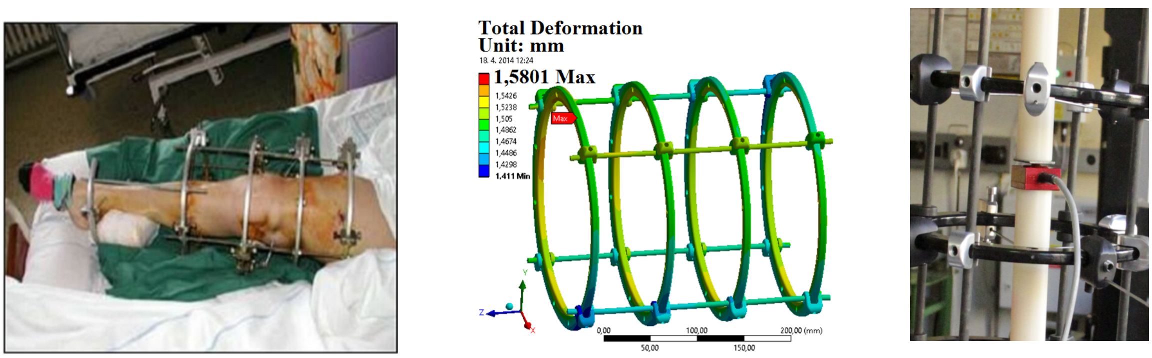

Fig. 5. External fixator for treatment of limbs a) application at the hospital; b) FEM (total displacement); c) experiments in our laboratory (force transducer).

References [1], [4] and [5] present a way of designing new external fixators intended for treatments of limbs. These fixators are in line with new trends in medicine, see Tab. 1. Numerical modelling and laboratory experiments (based on previous techniques) provide support during the research and design process, and represent very important parts of the solution; see e.g. Figs. 5 and 6.

Conclusions

Complicated fractures represent an important therapeutic problem. According to the results and applications presented in this paper (i.e. some examples of external fixators for the treatment of limbs, the pelvis and its acetabulum), 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. According to the results, the improvements in the design of fixators are evident. The VŠB – Technical University of Ostrava, together with the University Hospital of Ostrava are cooperating with the Czech company MEDIN a.s. This work was supported by the Czech projects FR-TI3/818, TA03010804 and SP2014/17.

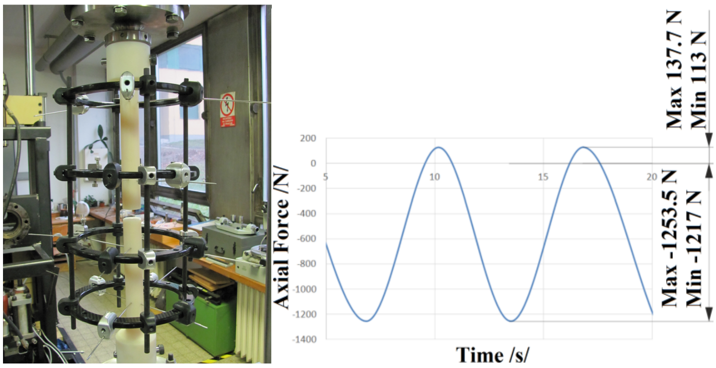

Fig. 6. External fixator for treatment of limbs (experiments in our laboratory - quasi-static cyclic overloading by axial force).

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