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Computational modelling of pelvic ring osteosynthesis by minimally invasive fixation techniques

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There is a variety of osteosynthesis techniques for medical treatment of pelvic ring injuries available. The presented study focuses solely on sacral bone fractures and related minimally invasive fixation techniques. The techniques employing either of the following are considered: the transiliac internal fixator (TIFI), the transiliac plate (TP) or the iliosacral screw (ISS).

Although there are several experimental studies on stability of the above mentioned techniques, e.g. on TIFI in [2, 5] or on ISS and TP in [1, 3], a serie of newly performed in-house experiments is performed. The experimental campaign is designed so that a high repeatibility of the recorded experimental data is achieved. In order to do so, orthopaedic pelvic models made of solid foam [4] are employed and mounted in a dedicated metal stand so that no displacements nor rotations are allowed in acetabula.

A special attention is paid to treatment of unilateral transforaminal fractures with absence of other affiliated pelvic ring injuries. Cases with either linear or comminuted fracture zone are considered, Fig. 1. Each examined fixation technique is analysed using a fresh pelvic model which is first tested in an intact state. Then the fracture is created and the fixation applied. During the tests, pelves are subjected to compressive loading applied at the sacral base.

The experimental measurements serve as a basis for development and validation of the computational model. The computational model geometry is based on the computed tomography (CT) images of the experimentally tested pelves with the applied fixators. This allows for a precise positioning and orientation of the fixators within the computational model. The finite element (FE) computations reflect the experimental setup including the boundary conditions and the material properties.

The homogeneous isotropic linearly elastic material model is applied for both the solid foam pelves and the titanium fixators. The parameters of the solid foam material model are identified based on in-house tensile and compression tests. Nonlinearity in the foam's elastic response and its viscoelasticity are negligible.

Between the two bone parts along the fracture line, a surface to surface contact problem with friction is utilised. A volumetric computational mesh consists of approximately $300\,000$ tetrahedral elements. The geometry of all fixators is simplified to elementary three-dimensional geometric shapes, e.g. the screw threads are omitted and a cylinder with the effective diamater of the screw is applied instead. Movement of the screw within the insertion hole as well as the relative motion of the fixator parts are fully constrained.

The computational model is fine tuned using the experimental data. The numerical results confirm the same trends as observed in the experiments. The difference between the computa-

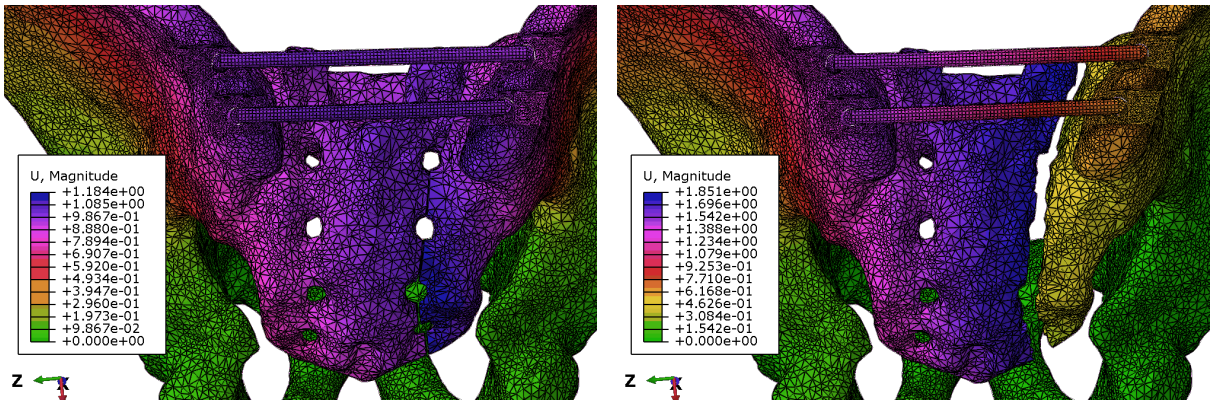

Fig. 1. Contour plot of displacement magnitude [mm] as computed by the FE model for dual TIFI fixation of linear transforaminal fracture (*left*) and transforaminal fracture with comminuted zone (*right*)

tional and the experimental data is in a range of percents. In case of the linear transforaminal fracture, a supraacetabular insertion of the selected fixator (TIFI or TP) provides superior stability of the pelvic structure. Opting for a dual fixation (either dual TIFI or dual TP) does not enhance the stability of the structure for the tested case. However, for the comminuted fracture zone, the differences between classical, supraacetabular and dual fixation techniques are insignificant. On the contrary, combination of supraacetabularly inserted TIFI or TP with ISS inserted into the first sacral joint significantly improves the mechanical stability of the treated pelvic ring for both linear and comminuted fractures.

A selection of the fixation technique influences not only stability of the pelvic ring fixation but also complexity and duration of the surgery, intraoperative blood loss and a level of risk of iatrogenic injuries. These other factors are not reflected within the study.

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References

[1] Berber, O., Amis, A. A., Day, A. C., Biomechanical testing of a concept of posterior pelvic reconstruction in rotationally and vertically unstable fractures, The Journal of Bone and Joint Surgery. British volume, 93-B (2) (2011) 237-244.

[2] Dienstknecht, T., Berner, A., Lenich, A., Zellner, J., Mueller, M., Nerlich, M., Fuechtmeier, B., Biomechanical analysis of transiliac internal fixator, International orthopaedics 35 (12) (2011) 1863-1868.

[3] Giráldez-Sánchez, M. A., Lázaro-Gonzálvez, A., Martínez-Reina, J., Serrano-Toledano, D., Navarro-Robles, A., Cano-Luis, P., Fragkakis, E. M., Giannoudis, P. V., Percutaneous iliosacral fixation in external rotational pelvic fractures. A biomechanical analysis, Injury 46 (2) (2015) 327-332.

[4] https://www.sawbones.com/full-male-pelvis-large-solid-foam-w-sacrum-1301.html

[5] Ueno, F. H., Pisani, M. J., Machado, A. N., Rodrigues, F. L., Fujiki, E. N., Biomechanical study of the sacroiliac fracture fixation with titanium rods and pedicle screws, Acta Ortopedica Brasileira 23 (3) (2015) 154-157.