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BIOMECHANICS – VERIFICATION OF FORCE CHARACTERISTICS OF A DEVICE FOR REDUCTION OF BONE FRAGMENTS IN PATIENTS WITH FINGER FRACTURES

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Abstract: *Finger fractures present a common type of fracture of the upper limb; they are most frequently caused with a direct mechanism of injury. These fractures are mostly unstable, indicated for surgical treatment (osteosynthesis of the fracture). The principle of osteosynthesis includes appropriate reduction (realignment) of the fracture, and its stabilization with an osteosynthetic material, most commonly using screws or plates. However, reduction of dislocated fractures is very difficult, that is why a new apparatus for repositioning of bone fragments has been developed, which may be simply used to reduce the fracture and maintain its appropriate position for subsequent osteosynthesis. The multifunctional apparatus makes repositioning of fragments in patients with finger fractures more easier, improves the quality of the final result and reduces the duration of surgery. In order to improve the quality of care provided for patients with finger fractures, it is possible to recommend introduction of this newly designed device into clinical practice (shortening of the operating time and the operating cycle). Laboratory experiments performed at the VŠB – Technical University of Ostrava provide a basic overview of force characteristics of fracture fragments compression induced by screwing the apparatus together in the course of surgery. The obtained results serve as a basis for introduction of the device into everyday clinical practice.*

Keywords: Biomechanics, Finger fractures, Device for reduction of bone fragments, Experiments, Compression force.

1. Introduction

In human hand, there are five bones in the palm of the hand (metacarpals), and 14 bones in the fingers (phalanges).

When a finger bone is broken, it can cause misalignment of the whole hand; see Fig. 1. Diagnosis of a finger fracture is based on physical examination and X-ray imaging. Without treatment, the broken finger may remain stiff and painful. People with weak bones (such as the elderly or patients with a calcium deficiency) but also manual labourers, athletes etc. have an increased risk of breaking their fingers. Therefore, it is important to perform and develop good methods for fracture treatment, see Karthikeyan (2013).

This article is focused on the evaluation of a new device intended for reduction of finger fractures; see Fig. 2. The obtained results (measured force characteristics, based also upon our earlier work, see Frydrýšek et al. (2015)) serve as a basis for introducing the developed product into clinical practice.

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Fig. 1: Phalangeal fracture and its treatment (i.e. repair with small screws).

Fig. 2: Device for reduction of finger fractures: a) with the drill guide; b) without the drill guide for insertion of screws.

2. Device for reduction of finger fractures

The designed device (see Fig. 2) should provide the physicians with an instrument for reduction of finger fractures. It is ergonomically shaped and adjusted for insertion of mini-screws with the diameter of 1 to 2 mm into bone fractures, in the course of surgical procedures performed on small bones of the hand. The size of the screw head varies, depending on the screw used, from 2 to 4 mm (according to the anatomy of individual patients). The direction of drilling is perpendicular. One part of the device contains a curvilinear arc with a fixed tip. The other part consists of a targeting case and a nut, enabling compression of bone fragments. Exchangeable cases enable drilling with a K-wire, or a drill, or insertion of screws during osteosynthesis, see Fig. 1b.

3. Measurement of force characteristics of the device for reduction of finger fractures

Due to the need to introduce the device for reduction of finger fractures into clinical practice, it is necessary to evaluate it also from the biomechanical point of view. The selected method of testing was to

perform measurements at laboratories of the VŠB – Technical University of Ostrava (Ostrava, Czech Republic, see Macura (2001)).

It is very important for the physicians to know precisely the capabilities of the device. From the point of view of biomechanics/mechanics, this represents namely its sufficient stiffness, reliability and exertion of sufficient compression forces Fc [N], depending on the displacement u /mm/ of the free end of the arc (the tip – left side of the device, see Fig. 2), in the axis of the clamping screw. This displacement occurs during compression of finger fractures and depends on the stiffness of the device.

According to the description above, we performed an experiment, which is documented in Figs. 3 and 4. In order to perform the measurements, the device was fastened into a clamp in the place of presumed zero deformation. In order to measure the Fc force, we used an adjusted strain gauge, with a membrane structure and nominal range of 300 N. For measurement of displacement of the end of the arc on the device we used a linear displacement sensor type HS25 (Vishay Precision Group, Malvern, Pennsylvania, USA). Both sensors were connected to a measuring apparatus, strain card and accessories (National Instruments, Austin, Texas, USA). The forces and displacements were recorded with software created in the LabVIEW interface.

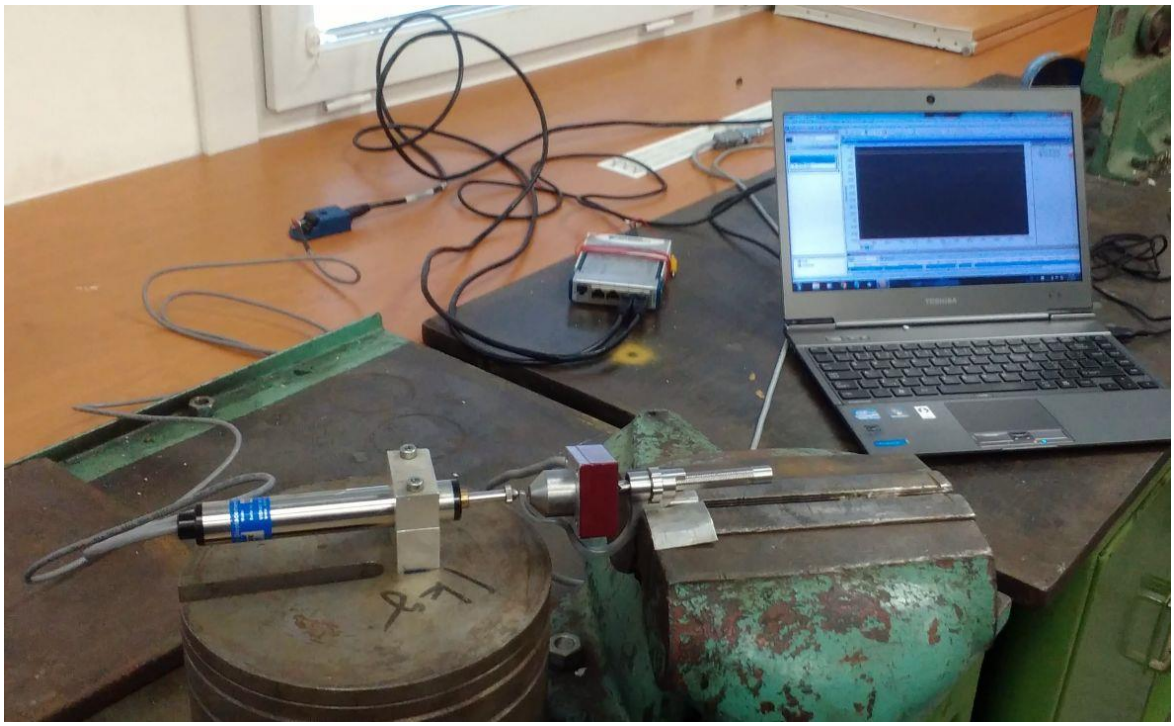

Fig. 3: Laboratory measurement.

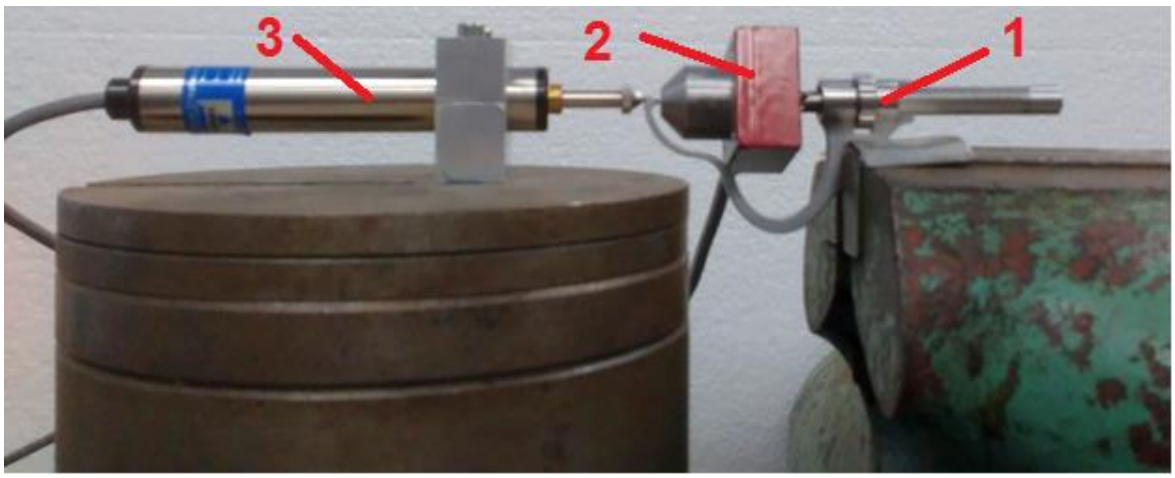

Fig. 4: Laboratory measurement: 1 device for reduction of finger fractures, 2 force sensor, 3 linear displacement sensor HS25.

4. Results of measurements

The results of measurements of compression forces in the device for reduction of finger fractures are presented in Fig. 5.

For practical reasons, the acquired dependence Fc = *f*(u) can be linearized via equation

$$\mathrm{Fc} = 44.857\mathrm{u}\,, \tag{1}$$

see Fig. 5.

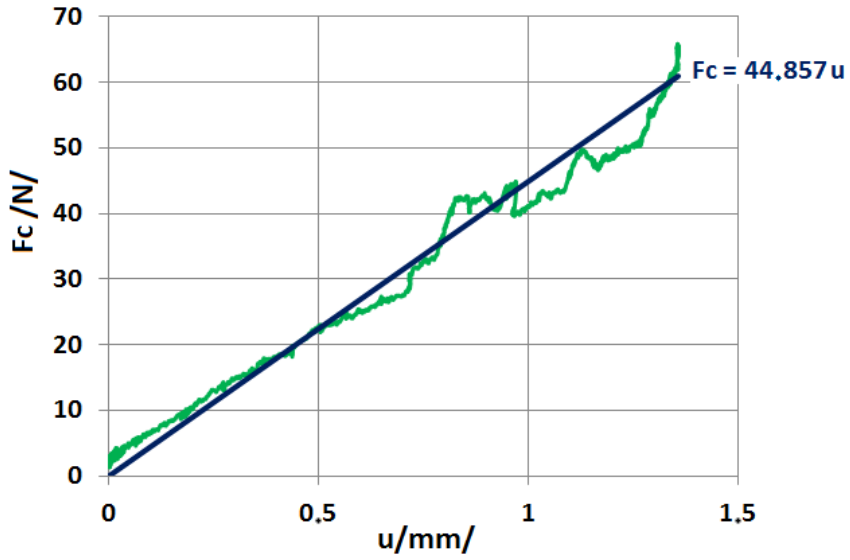

Fig. 5: Dependence of compression force on displacement (measurement and its linearization).

5. Conclusions

The results of measurements proved sufficient magnitudes of compression forces required for osteosynthesis performed with the newly designed device for reduction of finger fractures. Measurement of dependency of these compression forces is what makes this article truly original. The maximum magnitudes of compression forces (i.e. an additive loading during the operation) reaching up to 70 N are sufficient for surgical procedures in traumatology/orthopaedics.

Based upon the experiments, it is possible to conclude that the device for reduction of finger fractures may be safely introduced into clinical practice, which will result in improvement of medical care provided for patients.

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