The 4th International Conference
″Advanced Composite Materials Engineering ″
COMAT 2012
18- 20 October 2012, Brasov, Romania

THE EVALUATION OF RELATIVE DISPLACEMENTS WITH VIC METHOD IN OSTEOSYNTHESIS OF TROCHANTERIC FRACTURES

A. Burnariu[1], R. Necula[1], B.P. Gálfi[1], I Száva[1], I. Şamotă[1]
[1] Transilvania University of Brasov, ROMANIA, adrian_burnariu@yahoo.com, ortomed.bv@gmail.com, bgalfi@yahoo.com , janoska@clicknet.ro , ortomed.bv@gmail.com

Abstract: The authors describe the implementation of a powerful optical investigation method (the Video Image Correlation-VIC) in the osteosynthesis of the trochanteric fractures. In order to perform an impartial/detached evaluation of the relative displacement of the fractured parts, there is necessary such experimental method, which allows both a high-accuracy and full-field monitoring of the phenomenon. The authors present their first approach in this sense. The proposed method, in the authors' opinion, will be widely applied by the surgical doctors in order to improve their fixing systems in cases of the trochanteric fractures.
Keywords: VIC, long human bones, trochanteric fractures, experimental method

1. INTRODUCTION

This kind of osteosynthesis (of the trochanteric fractures) presents several difficulties from the experimental investigations points of view. In order to establish the behaviors of the different fixing systems of the fractured bone parts, there are several experimental methods, but most of them present a lot of difficulties. In the following are presented some important preliminary aspects. The deeply analysis of the biomechanical conditions of the fixation protocol for the fractured long human bones was started in 1958 by the so-called *AO school* (*Arbeitsgemein-schaft für Osteosynthese-fragen*) and continuously improved [8]. Their classification contains in fact a high-accuracy deeply identification method (in 4-levels); figure 1 offers its first level.

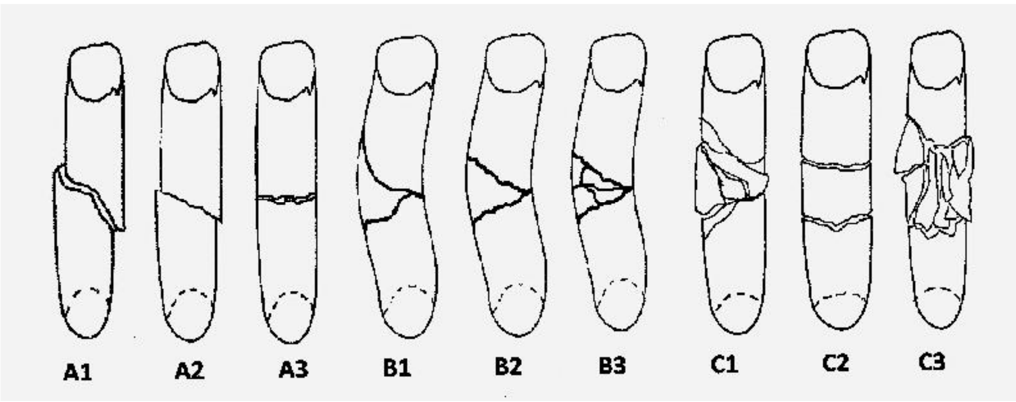


Figure 1: The first level AO classification [8]

It is well-known fact that the fixing of the long fractured bones, requires respecting some biomechanical conditions. It was established the piezo-electrical behavior of the human bones (under mechanical loading it produces some small electrical signals/impulses, which encourage/promote the developing/formation of the primarily callus and consequently reduces the healing process period). Based on this fact, Professor Perren elaborated his theory [12-14], where he establishes/states, that small relative micro-movements of the fractured bones parts will present favorable condition for the healing period diminishing. Taking into the consideration the fact, that there are several fixing system/procedures; part of them allow, and the others exactly prohibit these micro-movements, *became very useful to investigate these fixing methods' behaviors from the point of view of the micro-movements and compared the obtained results with the clinical praxis' ones*. A remarkable set of tests were performed by the authors of the contribution [7] in order to establish some high-accuracy mechanical characteristics of bones in some special conditions. Depending on the real mechanical characteristics of the fractured bones, one can select the optimal fixing system, too. In the References, are presented some useful experimental approaches of the fractured long human bones sub-system stress-strain states evaluation, where were applied several (experimental) methods (Photo-Elasticity of the thin layers, Electro-tensometry (the Electric Strain Gauge method), Holographic Interferometry, etc.). In the case of the *photo-elastic thin layers* [1-6] not only the locally increasing of the stiffness but also its low accuracy represent its main disadvantages. Supplementary, this experimental method is not able to evaluate the relative displacements of the fractured parts, which represents in facto one of the most important parameter of the investigations. The *Electric Strain Gauge method* [9-11] requires some special and very expensive strain gauges, able to monitories the relative displacements, but unfortunately, only in a very small range of the displacements. In addition, they offer the strain values, not the displacements ones. The *Holographic Interferometry* is an optical full-field and non-contact method, but its main disadvantage consists of the very small range of the acceptable (which can be monitories) displacements (up to approximately 300 *nm*). This very small interval of the displacements can be improved by measurements in "cascade" (applying several intermediate loading steps), but the total cost and spend time of the investigations became prohibitive. If one thinks on *Moiré-fringe method*'s applying, it requires special kind of grids and also its accuracy is a little bit low (taking into the consideration of the proposed Video Image Correlation's one). One other general difficulty of the mentioned methods represents the very small area, where all of the applied methods have to be dispose (fix) their measuring elements. In order to fulfill - in the case of *the fractured long human bones* - the high-accuracy investigation's requirements, the authors choose the **V**ideo **I**mage **C**orrelation method. Its 3D version (*VIC-3D*), from ISI-Sys GmbH, Kassel, Germany [24; 25], corresponds in the best manner to the proposed investigations' requirements.

2. THE PRINCIPLE OF THE VIC-METHOD

In the reference [15] is described the theoretical background of the Video Image Correlation (or in several references: the Digital Image Correlation –DIC) method.

Figure 2: The VIC-3D system [24; 25]

Briefly, one can mention *some of the main advantages of the method*:

- it is a full-field contact-less method;
- eliminates the rigid body movements from the achieved values, and consequently can be applied in normal working conditions (not only in labs);
- has a good accuracy (up to approx. $1\ \mu m$) in 3D displacements fields;
- offers not only the displacements field, but also the strains' ones;
- presents a large interval/range of the measured values of displacements (starting from some *micron*s up to several *cm*) without any special supplementary preliminary preparation requirements;
- allows the data extracting in different manners [e.g.: in Excel (cvs-files), respectively using metric node mapping, similarly with the FEM-analysis one];
- has a good stability, allowing high-accuracy measurements in operating conditions.

In principle, the VIC-3D system consists of two high-resolution video cameras, mounted on a tripod by means of a high-precision connecting rod (see figure 2). The surface of the tested object is sprayed in advance with a water-soluble paint, in order to obtain a non-uniform dotted surface; the sizes of dotes depend on the surface sizes.

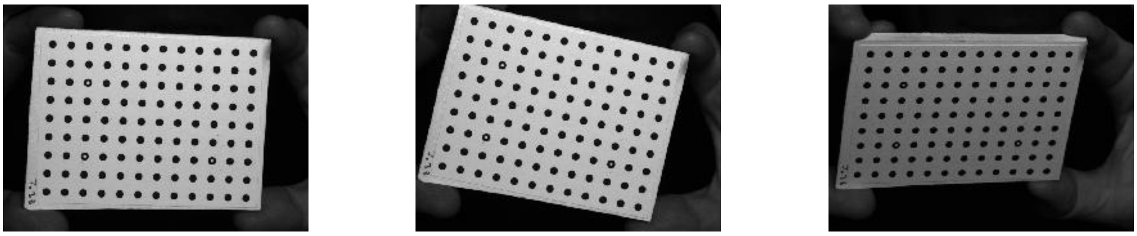
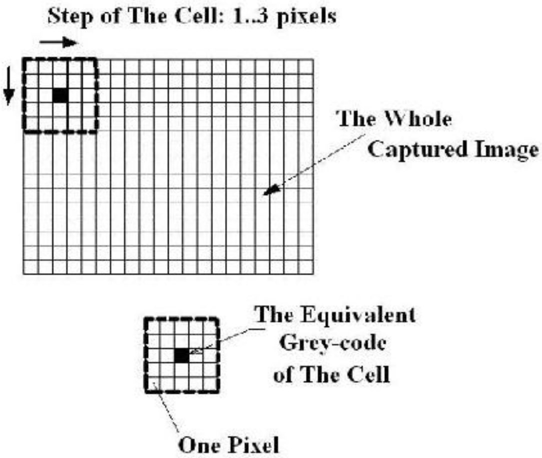


Figure 3: Different stages of the calibration process of each camera

After the calibration (see figure 3), the cameras will perform the image acquisition in an $[n \bullet m]$ matrix of pixels, firstly for the unloaded tested specimen (where on has to define *the area of interest*) and after then: for the loaded one.



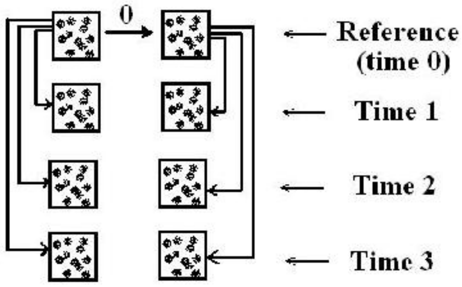


Figure 4: The measuring principle based on the scanning procedure

Figure 5: The stereo images analysis

On the unloaded state's images the soft-ware allows the pre-selecting of a *Subset*'s (primarily cell) sizes (e.g.: $5 \bullet 5 = 25\,pixels$), respectively the step-magnitude (step size) for moving/translating of the Subset in horizontal and vertical direction (see figure 4). For this Subset the program will establish/determine an unique grey-code, correlated to its median pixel's high-accuracy 3D positioning. By analyzing of the whole image (having each an $[n \bullet m]$ matrix of pixels), this will be substituted by these median pixels of the Subsets.

After loading of the tested specimen, for all captured images (only in the area of interest, of course!), the program will identify the new positions of these Subsets, by performing an adequate comparison: *only once are compared the left and right images* (at time 0), after than, the succeeding left images are compared to the left reference, and succeeding right images are compared to the right reference (see figure 5); so the image processing became faster.

Due to the fact, that the captured images for the loading states, are similarly analyzed and compared with the initial state's images, finally, for every representative median pixel will be obtained the displacement vector. Using these values the soft-ware offers for each representative median pixel: the strains and main strains, too.

3. THE PROPOSED METHODOLOGY

In the authors, based on their previously practice, propose the following methodology. Each fractured bones, foreseen with different kind of fixing systems, respectively adequately prepared (painted how was mentioned before), will be subjected to compression up to a quote of the normal loading of the human legs (e.g.: 150 *N*) in an universal tensile-compression testing machine. In order to allow the opportunity of an adequate statistical evaluation, each fractured bones are monitored during several cycles of loading and unloading. For every loading cycle are performed, in the same conditions, image capturing. On the captured images is predefined the area of interest, where the soft-ware will perform the adequate displacements' calculus. On this area of interest are marked a number of representative/significant points at the both sizes of the fracture (see figure 6).

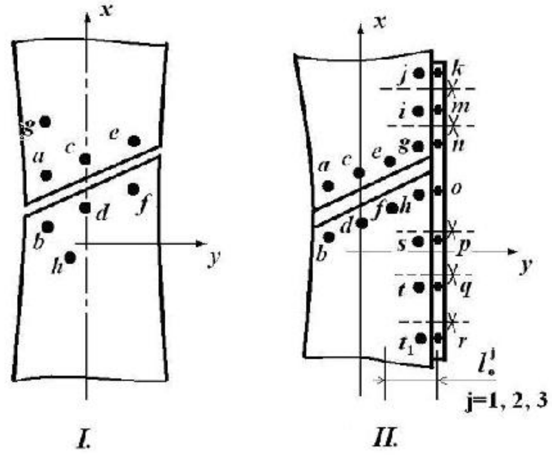


Figure 6: The selection modality of the significant/interesting points on the tested bones:
I. a simply unstable fracture; *II.* the case of the plate-fixators

For each significant pair of pre-selected points are determined by soft-ware the corresponding coordinates, respectively all components of displacements field and of strains.

For example, to the pair *a-b* are determined: their initial distance ℓ^0_{a-b}; the elongation/shortening $\Delta\ell_{a-b}$; their projections on axes *x* and *y* [(x_0, y_0); (u, v)]; respectively the corresponding strains ε_x , ε_y .

One can agree with the fact that an optimal monitoring of the displacements' and the relative displace-ments fields has to be independent from the initial co-ordinates of the above-mentioned selected points (*a, b, c, d,* etc.). Consequently, in the authors' opinion, a better evaluation can be performed taking into the consideration the strain values along the axes *x* and *y* axis instead of the displacements' components. In figure 6, *I* is presented a common case, where is applied an internal fixator system.

Here, for a better monitoring (and evaluation) of the fractured parts' movement was selected supplementary the pair of points *g-h*, located/disposed at a certain distance from the fracture.

This pair of points serves as a reference for the further evaluation of the displacements and strains. In the case of the plate-fixators (see figure 6, *II*), supplementary are selected a well-defined number of pairs (*j-k,…,* t_1-*r*) in order to monitories the relative displacements of the fractured bone part and fixator plate. In this case also one can select a pair of "reference points" (similarly with the pair of points *g-h* from figure 6, *I*).

4. THE ILLUSTRATION OF THE PROPOSED METHOD

In the figure 7 is offered as illustration of a vertical displacement graph for one of the selected pair of points during a complete loading-unloading cycle.

One can remark also the opportunity of the hysteretic loops' monitoring, too.

Based on the described method, the authors intend to perform comparative and high-accuracy investigations on different type of fixing systems in order to evaluate their advantages and limits in clinical praxis.

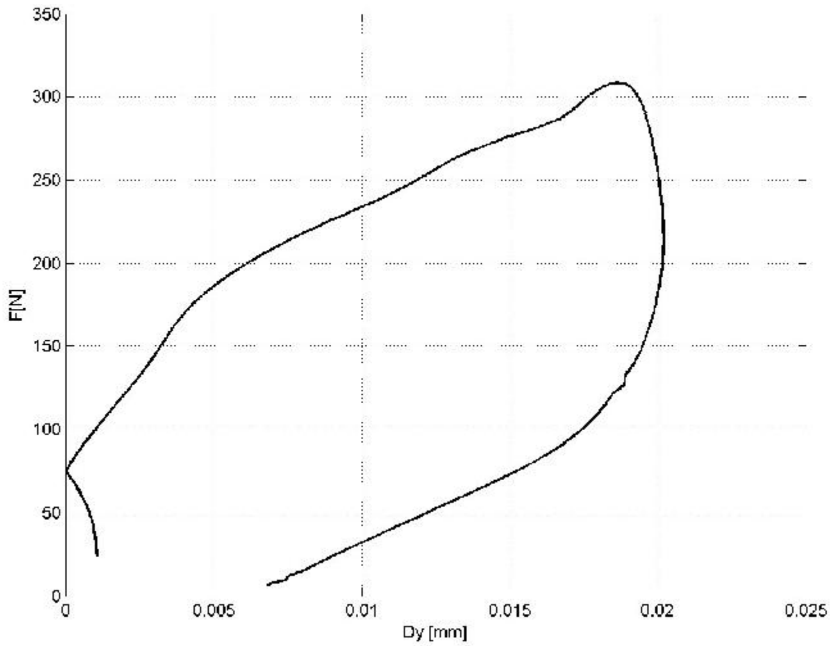


Figure 7: The vertical relative displacement ($D_y = \Delta$ v) versus loading force (F)

3. CONCLUSION

In the authors' opinion, the obtainable results will offer several important and useful biomechanical conclusions, applicable by the surgical doctors in their clinical praxis. Also, by comparison of these potential results by VIC-3D with the clinical praxis' ones, became possible the better selection of the fixators systems, depending on the fractured bones' particularities.

We hope sincerely, that the VIC-3D method will represent in the next period a very useful and powerful one in Biomechanics. In the next period the authors intend to continue these investigations on several useful clinical cases.

ACKNOWLEDGEMENTS

By this way, the authors express their gratitude and their special thanks to ISI-SYS GmbH, Germany (www.isi-sys.com) and Correlated Solution Company, USA (www.correlatedsolutions.com), for their help and assistance in the use of the VIC-3D (2009) program. Without their generous help, was not possible to become initiated into the above-described experimental method.

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