SPECIAL KINDS OF DIAGNOSIS IN THE EXTERNAL OSTEOSYNTHESIS

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Abstract:

This paper includes the idea of the external osteosynthesis diagnostics system that is functionally connected with device, which is an integral part of the external fixation system. The data and information about the condition of the bone tissues, which are going to healthy can be recognize in many ways. The verification of the recognition process is very expensive and it is going to give up in the non-discussed cases. The fixation system, which is using to stabilize a mechanical environment of the broken bone, is very important. However, in order to realize the postulate of the active healing the chosen one is the fixator that belongs to the one-sided family. The internal device has to take the mechanical impulses from the frame of the mechanical stabilizer and create the short simulation of the expected mechanical loads. Motorized system can in this case provide the result of the simulation to increase the strength of the mechanical system to carry greater load in the closest future. If the predicted load is too high, frame is transmitting the vibrations and then the tentative stiffness can be fixing.

Introduction

External osteosynthesis is a method that should create the right environment for the healing process and in this way influent on to the osteogenic processes. The phenomenon that occurs between pieces of the fractured bone is very hard in describing. The profile is dependent on time and is different in each case of healing. The patient and his life history are determining in a large extent the profile of this phenomenon. The destination of all healing processes is always the same: fix the broken natural parts of the body and recover the right function of the biological organs. However, the aim is common the track to reach them is rarely the same. It depends not only from the difference between organisms but also on the profile of the environment that is inseparably connected with the body and influent directly on its condition (physics, mental, economics).

We can tray to describe the state of the fractured bone and take the information from the fixation system that can be helpful in further diagnostic process. Creation of the parallel diagnostics methods can have positive effects. It gives the doctor the tool for the verification of his diagnosis.

Methods of Diagnosis

One of the most respected methods of the broken bone healing in the external osteosynthesis is Ilizarov fixation system (Fig.1). In this case, the pieces of the injured limb can be fixed and using the artificial parts, the strength of the limb can be increased to the secure level. This basic system is marked by the high stiffness but also non-ergonomic construction.

Figure 1 Ilizarov fixation system - on leg
(http://membres.lycos.fr/ilizarov/grosplan.jpg)

Existing diagnostic methods give us today information about the static state of the patient. Thus the physicians tray to predict the direction in which can the osteogenic processes go and in this way they are trying to make a good match of the regeneration profile to the selected patient.

Nowadays medicine mainly bases on the images and its creation process is supported by very complicated and expensive methods. Each of this method can give us lots of the information. However, its possibilities none of them have ability to give clear answer to the basic question: 'How much load can carry the broken leg at the specific moment' (Fig. 2).

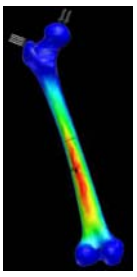

Figure 2 Loaded bone – ANSYS simulation

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To make it possible we have to measure the real mechanical parameters describing the mechanical profile of the adhesion zone. It's very complicated and almost impossible.

Because of the reason physicians are aided in choose by lots of non-destruct diagnostic methods like biochemical analysis, MRI (Magnetic Resonance), X-Ray (Radiology), USG (Ultrasonographics), densitometry (Fig. 3).

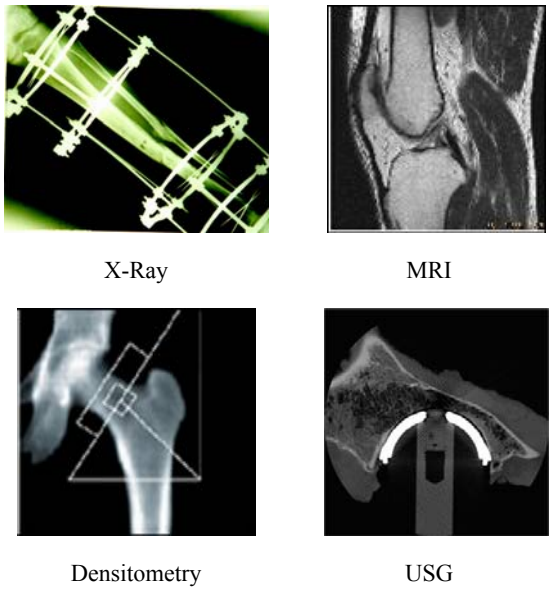

Figure 3 Diagnostic methods based on images analysis (source: WWW)

There is many ways to strength the limb. One of the most known is the Ilizarov fixation system but there are many other propositions. Most of the modern fixators were created basing on the experiences taken from the Ilizarov fixation system. Some of them knowingly have decreased secure level. Instead, the high rigidity these solutions give us possibilities to stimulate the cell growth process by making ability to give micro movements in the fracture of the broken bone. This phenomenon is confirmed by clinical observation and is common known. In accordance to this observation has been formulated an active healing postulate. The idea of this proposition includes the fractures micro movement ability as a one of the most important thing in the external osteosynthesis healing method. These assumptions give us lots of fixation systems solution that give possibilities to realize the micro movement.

Dynastab Mechatronics 2000 (Fig.4) belongs to this group of solutions. This one sided stabilizer give us possibility of distract and compress the fractured zone. It gives many additional possibilities in curing other bone illnesses.

This construction has also an original diagnostic module (Fig 4). It gives information about the part of the total load that the frame of the Dynastab is carrying at the specific moment. Because the stiffness of the passive dynamic chamber and weight of the body are known, it is possible to calculate the approximated stiffness of the adhesion zone and further the load that the adhesion zone is able to carry without destruction.

Figure 4 Dynastab Mechatronics 2000 fixation system

Phenomenon of the natural dynamisation in the fracture of healing forces us to understand the processes that are appearing in the region of new bone tissues synthesis. Complexity of the healing process depends on the number of affecting factors. The people who are connected which the broken bone healing with application of the external fixators observed that the healing process is shorter if the pieces of broken bone have controlled movement ability [2,3,4]. Controlled force impulses that are localized between pieces of the fractured bone can stimulate the process of new bone tissues synthesis and increase the durability of the coming into being bone structure. The profile of that phenomenon is changing all the time.

Scientist planed to take a full control over the mechanical environment of the broken bone system, which is a very important factor in the treatment process. This is the way to assure the doctors that the primary condition of the healing process was fulfilled.

One of the originally solutions is proposition of the polish scientist. It has been taken trial of describing mechanical profile of the broken bone-fixator system (Fig. 5) [3].

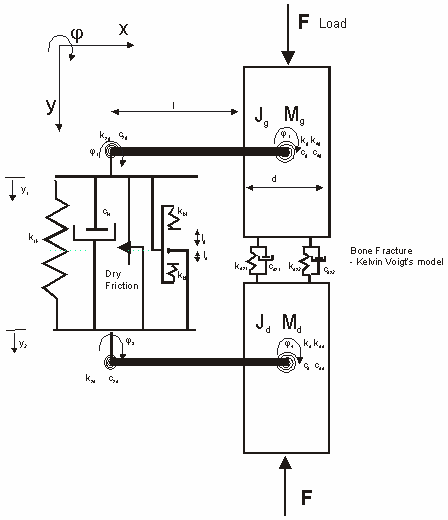

Figure 5 Nominal model of the external fixation system with dynamisation chamber applied

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Fixator Dynastab Mechatronics 2000 has been equipped with the measurement module (Fig. 4) that can help to describe the loads that the fixator frame and the adhesion zone have to carry. Creation of the computer simulation trial has been also taken. For the simulation has been Kevin-Voight adhesion model used (Fig. 6) [1].

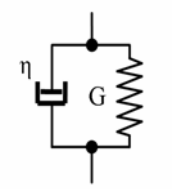

Figure 6 Kevin -Voight rheological model

Propositions

The most important thing is to create the models of the mechanical system that can describe lots of the factors coming from the daily life. Some aspects of securing the adhesion zone are very complicated and force to take into consideration also the most incredible determining factors.

The biological subsystem is very hard to describe. However the fixation system ought to base on some model that describing the biological subsystem: the parts of the broken bone, the adhesion zone and the mechanical relation between them. One of the usable models of the adhesion zone can be Gubanov rheological model (Fig. 7) [1].

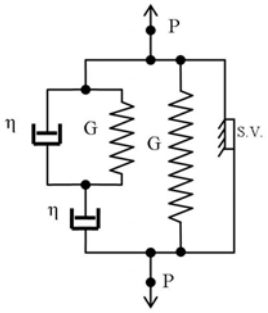

Figure 7 Gubanov rheological model

Using this mechanical non-linear model, we can approach to the real, time determined profile of the fractured bone. We can also try to make simulation of the fractured bone and take information about the answer of the bone system onto the time changeable loads that can occur in the real life.

Micro movements of the broken bone pieces that are occurring in the adhesion zone should be under control. Range and frequency of the vibration localized in that zone are very important for the adhesion processes. In some way, the profiles of the adhesion bone loading influent on to the future mechanical characteristic of the healed bone (Fig. 8). Characteristic parameters describing the mechanical properties of the dynamical chamber are depending on period of the treatment. The values should change in order to change of the bone adhesion mechanical features.

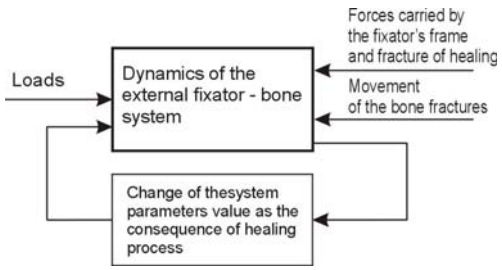

Figure 8 Evolution of the adhesion processes

The most important assumption is that we can influent on to the dynamisation process (micro moments realized by fixator) and in this way tray to change the mechanical profile of the adhesion zone during the healing process. It is coming to mind that the application of micro drives and sensor in the external fixators is a next step of their development [5].

Active dynamisation module, because in that way we will call this solution, should exchange basic passive dynamic chamber for the active one in the existing constructions of fixators.

There are three requirements connected with this proposition that have to be fulfilled:

- fixator construction have to secure the adhesion zone before the unexpected loads,
- dynamisation module have to be a part of the broken bone diagnosis system,
- dynamisation module has ability of active influent onto the profile of micro moments in the adhesion zone (active actuator).

Type of the diagnostic system depends on the type of the dynamisation module profile. Micro drive system is coupled with a measuring system of the load of the callus with feedback may play a role of a "doctor" who sets a level of the bone load dependently on the state of its regeneration (Fig. 8) [1,6].

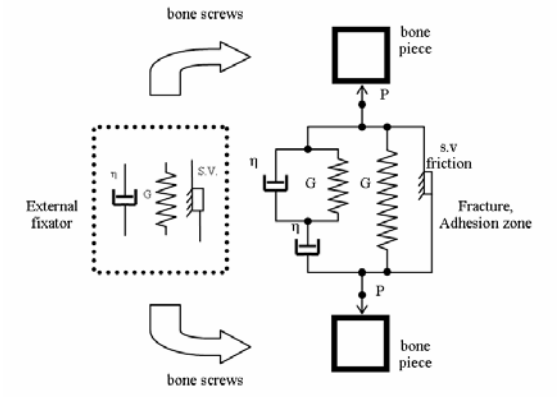

Figure 9 External fixation system with non-linear adhesion zone profile

New diagnostic method based onto the assumptions of the Dynastab Mechatronics 2000 creators. However,

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the new method has to be extends of his predecessor. It should give ability to make analysis in dynamic mode. It means that during the normal work mode of the fixator ought to be made all measurements.

Free vibrations appearing in the healing zone almost always causes dangerous condition in the healing environment. In this case existing vibrations are not recommended. Dangerous loads values can cause rising the brake in the existing bone adhesion and determining the pathology environment for the bone treatment process [4].

Vibrations are not undesirable only. In case of the active dynamisation applying the phenomenon of the vibration absorption can be used to proof the mechanical and organics structure. The deformations of the characteristic profile of the testing waveform can give us information about correctness of the bone structure and also about its mechanical properties.

The dynamisation module activates the testing procedure. Mechanical drive is putting into the adhesion zone the testing force impulses with known amplify and in regular period. The change of the movement range achieving during the healing process can gives us information about increasing stiffness of the bone system with considering the adhesion zone.

At the beginning of the treatment process when the structure of the bone adhesion has not high value of stiffness and the coming bone tissue structure is characterizing high elasticity properties should be used to the tests constant bone fractures movement range as the fundamental criterion of this process.

The features of the young bone tissues is different then the properties of the "old" bone adhesion which has higher load to carry capability. The "old" bone structure has to be tested using constant load as the main testing criterion. In this case, should we observe change of the bone fractures range movement.

It allows receiving the characteristic signal from the adhesion zone that can tell us lots about condition of the bone adhesion. In this way, we can provide about the correctness of the treatment process.

Each type of the bone adhesion is described by different signal, so we can predict appearance of the pathology during the bone healing process. It creates the new possibilities in the diagnostic domain and allows knowing the individual bone's features.

Application of the suitable algorytms of loading and unloading for coming adhesion zone diagnosis can create ability to make full mechanocal profile diagnostic coming into being new bone tissue.

Conclusions

In the present days, the evolution of the aiding systems in medicine is very fast. There are many reasons of this situation. First of them is undoubtedly fast progress in material engineering domain. Second one can be increasing people expectation to keep ability of the active life manner. Permanently increasing quality of life causes growth in the other domain of life

Appearing stimulus in the region of fracture increasing an activity of bone cells has beneficial influence for our health and mood. Wide known fact is stimulating the cells in due time and in due place. It can extract energy to rebuilt the old bone structure or to create the suitable environment for different kinds processes running in the live organism's bodies. Also the known fact is the lack of external impulses to going the degradation of an organ. There is an connection between occurring of the external impulses stimulating activity of the bone cells and the patient's healing progress. The experiments and clinical observations constitute the proofs of this connection. Recently registered a positively effects in stimulating of the fracture healing region.

The problem in increasing the speed of broken bone healing process and securing the right parameters of durability is not the new one. In the past some systems based on the passive solutions of dynamisation was applied. This solution allows the limited impulses of force in the region of fracture to work. Common feature is that the source of the working forces was always the part of the weight force.

Creating the ability to giving the controlled loads in the region of fracture is the first step to give medicine the tool to control the full healing process.

Applying the force systems with the ability to work in the accurate defined range and in order in the specified characteristic (with full control over the frequency and amplify of the dynamisation module work) is designed to make a precisely analysis of the bone fracture healing.

Scientists are still searching the new ways to proper influent into the broken bone healing process.

References

[1] MORECKI A., EKIEL J., FIDELUS K. (1971): 'Bionika ruchu', *PWN*, Warszawa

[2] BASTINI G., ALDEGHERI R. (1986): Dynamic Axial Fixation. A Rational Alternative for the External Fixation of Fractures , *International Orthopaedics*, Springer-Verlag 1986,

[3] JASIŃSKA-CHOROMAŃSKA D. (2001): 'Modelowanie i symulacja w projektowaniu jednostronnych zewnętrznych stabilizatorów ortopedycznych', *Oficyna Wydawnicza PW*, Warszawa, 2001,

[4] CHEHADE M.J., POHL A.P., PEARCY M.J., NAVANA N. (1997): 'Clinical Implications of Stiffness and Strength Changes in Fracture Healing', *The Journal of Bone and Joint Surgery*, vol. 79-B, No 1,

[5] JASIŃSKA-CHOROMAŃSKA D., KOŁODZIEJ D. (2004): 'Micro drive in Active Aiding of External Osteosynthesis Healing Process', *Elektronika*, no. 8-9, p. 138-140,

[6] KOŁODZIEJ D. (2004): 'Applying the Force Vibrations in the External Fixator-Bone System', *Machine Dynamics Problems*, vol.28, no. 3, p.163-169,

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