CHAPTER V
FINITE ELEMENT ANALYSIS OF THE KNEE JOINT WITH VITALLIUM BIOMEDICAL ALLOY IMPLANT

5.1. Introduction

Engineers and surgeons are applied, not pure scientists; both need some creativity in order to perform their professions. Some art is applied in medicine to decide where, how and when to perform an operation, or any procedure, such as an engineer whom needs to decide based in his personal experience how, when, where, what to do in any machine for example. [44]

Engineers art is applied to structures, machines, factories; but in the case of surgeons their art is applied to the human body, and the knowledge and experience of the doctor is always very important since his art most be fitted to the needs of the patient. Of all the clinical sciences, surgery is the most mechanical. So biomechanics is basic for many surgeon tasks. When biomechanics is misapplied or ignored there is likely to have a tragic or critical consequence for the patient.

Disruption of the skeleton by trauma is one of the major areas of interest to orthopedic surgeons, but there is very little analysis of the biomechanics of the functions of the skeleton and its response to stresses. Studies on the mechanics of the skeleton are being done, but unfortunately there are very few orthopedic surgeons with mechanical principles knowledge and also in the other way around. [44]

5.2. Fracture

5.2.1 Important Anatomic Knowledge

- Tibia is a bone designed to support the load of the body weight, it has several areas with a lack of muscle, which determines vascular poverty; especially in the distal half of the bone.
- Frequently, the fracture is due to a violent and direct trauma.
- The interbony membrane, fixed to the tibia and fibula from superior to inferior ends, gives a strong fixedness to the pieces of the fracture, limiting the axial and lateral displacement. [96]

5.2.2. Definition

The fractures presented over the limit between the proximal and distal plane correspond to fractures of the superior metafisis of the tibia; the fractures presented below this limits are called fractures of the distal metafisis; and the fracture presented in these limits is called fracture of the diafisis of the tibia. [96]

This study will be specifically for a superior tibia fracture as shown in figure 5.1, which corresponds to a fracture of the superior metafisis of the tibia.

Fig 5.1. X-Ray of the fracture

5.2.3. Classification

Fractures in the tibia are classified according to four points of view.

1. Localization
    a. Superior third
    b. Medium third
    c. Inferior third
2. Mechanisms
    a. Direct impact
    b. Indirect mechanism
    c. Torsion
    d. Shear
    e. Flexion
    f. Compression
3. Anatomy
    a. Transversal
    b. Oblique
    c. Conminuted

4. Load of the trauma that caused it
    a. High energy
    b. Low energy

The information given by the patient according to these classifications, added to clinical data as age, damage of soft parts, mechanism of the fracture, magnitude of trauma, exposition of fracture, deviation of fragments, allow a very exact clinical orientation about which treatment to follow that may modify the forecast and procedure. [96]

5.2.4 Treatment

There are two important moments of the treatment, the emergency treatment and the definitive treatment. The first one is the one needed and performed at the moment and at the place of the accident; it corresponds to a critical and dramatic moment because of the circumstances of the accident and the anxiety and pain caused by the accident. The procedure is simple but important and consists in not moving the patient, immobilize the leg and fix with some bandage. This procedure should not cause any additional pain, if there is any analgesic, to be used immediately. [96]

The definitive treatment involves a surgery. In most of the cases, the surgery is not needed, but in the case of oblique fractures, it is needed to use screws for fixation and after that proceed to immobilize with a bandage of plaster for at least 3 months. The screw fixing method in these type of fractures is easy because of the easy access of this bone. But this also produces a high amount of risks for the patient, and this is why this surgery must be performed for a extremely competent surgeon in this subject, in an excellent hospital with complete instrumentation; because, for this surgery there is no chance for improvisation.

Once all the precautions where taken the procedure described in Chapter III is followed.

5.3. Screws

The function of the screw is to apply friction between the bones. When load is applied to a bone fixed, the load resisted by friction at the bone interface and by transfer of load, to the screw.

Replacement prosthesis should be expected to withstand the repetitive stress and strain of weight bearing and motion that occurs in the joint over a life span of approximately 30 to 40 years. Secure implant fixations are paramount to implant longevity. Wear debris generation may result in osteolysis, which might lead to implant loosening and subsequent segmental instability. Furthermore, implant migration may have catastrophic effects due the proximity of important nerves, muscles and veins.

In total joint arthoplasty, implant fixation has centered on the use of methylmethacrylate cement or the use of implant surfaces designed to promote bone in growth. Due the proximity of vital elements, the use of cement for implant fixation is not currently considered a viable option. [41]

There are different types of screws used to hold bones. These may be:

- Cortical screws
- Cancellous screws
- Cannulated screws
- Lag screws

The screw used in this analysis belongs to the last category, lag screws. These are used to provide inter fragmentary compression. It can produce up to five times the compression of a plate. In order to get ideal inter fragmentary compression, it is needed to use the screw oriented perpendicular to fracture line and drill a hole.

Screws are subjected to considerable loading and can fail by fatigue. This risk can be reduced by applying maximum torque on insertion. This increases the friction and reduces bending moment on the screw from fracture loading.

5.4. Case studied

In order to analyze the behavior of a vitallium screw in surgery was selected a real case of an oblique fracture in the tibia of a healthy man of around 25 years old. The fracture analyzed is previously shown in fig 5.1.

5.5. Analysis

To perform this analysis, the same procedure than was mentioned in Chapter IV was followed here, with the difference that now we have a fully threaded screw of 40mm length placed in the approximate location of the fracture shown in fig 5.1.

At the beginning, the screws are not subjected to any significant stresses, but after 3 months of immobilization the plaster is removed and the screw remain in the bone for the rest of the patient life and is subjected to the forces presented in the human body.

The same assumptions made in Chapter IV in order to make a biomechanical analysis according to geometry, material, structure distribution and boundary conditions were applied here too, but with one more assumption, the torque applied in insertion was the maximum in order to have ideal results.

For this analysis, we took into account some of the theoretical standard properties of vitallium such as a density of 1.7 g/cm^3, a Poisson´s ratio of 0.31, the Young modulus of 218 GPa and a thermal expansion coefficient of $10*10^{-6}$ 1/K. [97]

The analysis was made with the considerations of a full foot strike stage because in that phase is where the most stresses were concentrated in the tibia, as shown in fig 5.2.

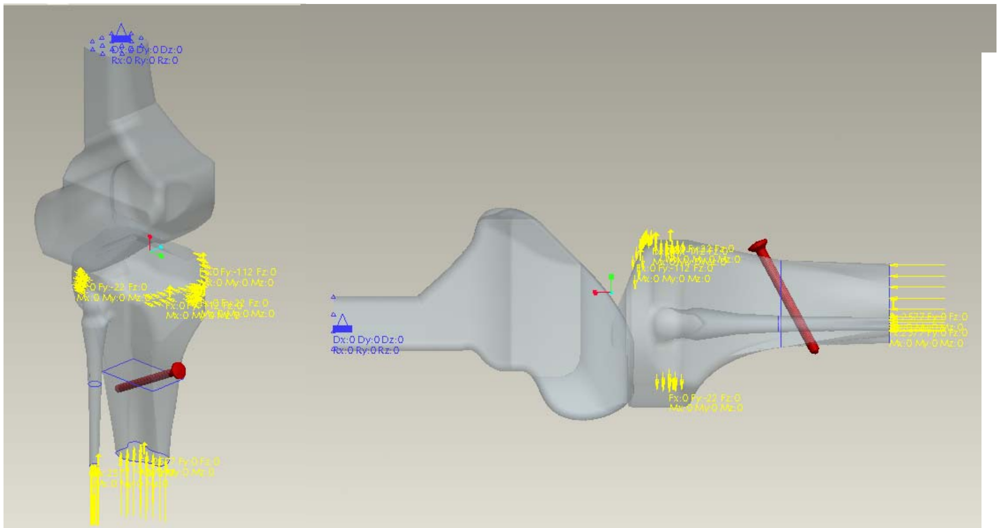

Fig 5.2. Drawing of model before analysis