LOCATION EFFECT ANALYSIS OF THE FIXATION PINS IN HUMERUS FRACTURE SURGERY

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Abstract. *A distal humerus fracture is one type of elbow fracture. The distal humerus is the end of the upper arm bone (the humerus) that forms the upper part of the elbow. They account for about 2% of fractures in adults. Since this fracture involve a complicated area, the normal method uses the application of screws to keep the bone pieces together, but this screws need to have the less possible influence on the bones when those are cured, that way there is a constraint in the maximum diameter and in the number of screws that can be used. As a elbow fracture, this region can sufer a torque and so the bones could go out of the normal position, the screws need to resist this torque. In order to determinate the optimum number of screws and a better position to than, this paper uses the Finite Element Method to make a structural analyses of the four most used configurations of screws: Two parallel screws and two orthogonal screws. This analysis simulate the bone fracture and the interactions between the bone pieces and the screws when a torque is applied to one of the pieces. The software used is the Abaqus solver with the HyperMesh pré/pós processor and the analysis utilize 3d elements to represent all the bodies involved. The two configurations are compared and the configuration that generated less tension on the screws is the optimum solution. To this analysis all the screws have the same diameter and the same material, also only the bones and screws are considered and any other variable do not enter in this test.*

Keywords*: Distal Humerus Fracture, Finite Element Analysis, Structural Analysis.*

1. INTRODUCTION

Daily, in hospitals and emergency posts, medics need to face a enormous quantity of injuries caused by the many accidents that keep happening all the time. Falls, car crashes and the like can cause many types of damages, between than this paper focus on bone fracture. When dealing with a fractured bone, the medics usually put it back in place and apply a plaster cover to keep it stable, in some more complicated cases it is necessary to fixate the bone with metal pins or screws, one of those cases is the Distal Humerus Fracture. Since this fracture involve a complicated area, the normal method uses the application of screws to keep the bone pieces together, but this screws need to have the less possible influence on the bones when those are cured, that way there is a constraint in the maximum diameter and in the number of screws that can be used. As a elbow fracture, this region can suffer a torque and so the bones could go out of the normal position, the screws need to resist this torque.

In order to determinate the optimum number of screws and a better position to than, this paper uses the Finite Element Method to make a structural analysis of the four most used configurations of screws: Two parallel screws and two orthogonal screws. This analysis simulates the bone fracture and the interactions between the bone pieces and the screws when a torque is applied to one of the pieces. The two configurations are compared and the configuration that generated less tension on the screws is the optimum solution. To this analysis all the screws have the same diameter and the same material, also only the bones and screws are considered and any other variable do not enter in this test.

This work aims to present the results of the comparison of the four configurations and demonstrate one possible application of mechanical engineering methods to help find optimal solutions in problems faced in the medicine field.

2. METHODS

2.1 - Humerus Fractures and Treatment

The elbow is a joint made up of three bones ð the humerus, radius, and ulna (Figure 1). It bends and straightens like a hinge. It is also important for rotating the forearm: the ability to turn our hands up (like accepting change from a cashier) or down (like typing or playing the piano).

The three bones that come together to form the elbow can break (fracture) in different ways. A distal humerus fracture is one type of elbow fracture. The distal humerus is the end of the upper arm bone (the humerus) that forms the upper part of the elbow. These types of elbow fractures account for about 2% of fractures in adults.

The elbow is a complicated joint and elbow fractures can involve both of the forearm bones, as well as the humerus.

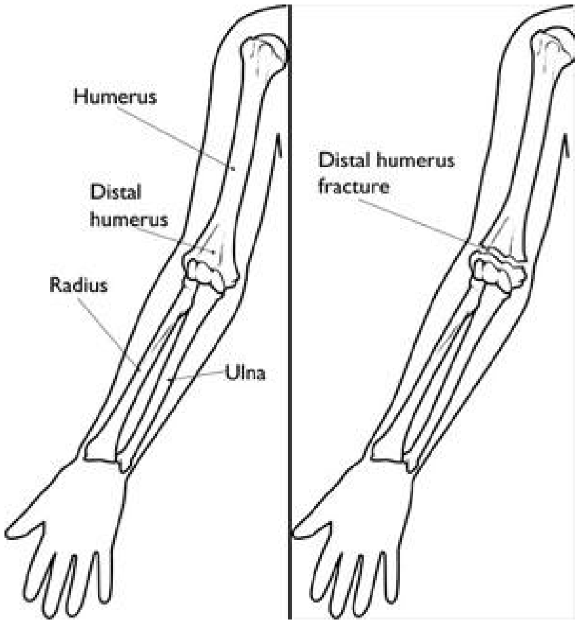

Figure 1. Distal humerus fracture.

The nature of the injury is commonly severe and is often associated with injury to surrounding soft tissue and nerves. To better understand the nature of this kind of fracture it is needed to take a look at the anatomy of distal part of humerus.

Humerus bone widens distally in the coronal plane to a maximum between the medial and lateral epicondyles and narrows from proximal to distal in the sagittal dimension before its distal most articular segment expands and juts anteriorly. This forms kind of lateral and medial column which diverge, diverging medial and lateral columns. At their most distal point, they are joined by the ñtie archò, consisting of the articular segment, the trochlea and the capitellum. The capitellum itself is the most distal portion of the lateral column and the trochlea is intermediate between it and the distal end of the medial column (Figure 2). The fracture typically occurs when there is a force applied to upper limb when the joint is flexed more than 90 degrees (SINGH, 2009).

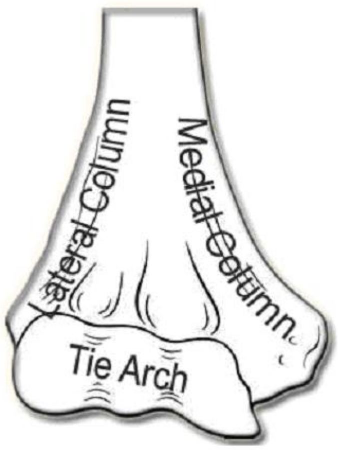

Figure 2. Distal humerus anatomy (SINGH, 2009).

Patients with a distal humeral fracture present with pain and swelling of the distal arm and elbow. Displaced fractures may cause a deformity and painful attempted movements. The patient should be given an above elbow splint after thorough examination of limb including neurovascular examination and x-rays.

This kind of fracture is classificated in three types: A-Type: Fracture is nonarticular; B-Type: A fracture of the B type is partially articular. A part of the articular segment remains in continuity with the shaft; C-Type: Fractures are articular, but have no articular fragments remaining in continuity with the shaft. In this work it was simulated only the A-Type fracture (Figure 3).

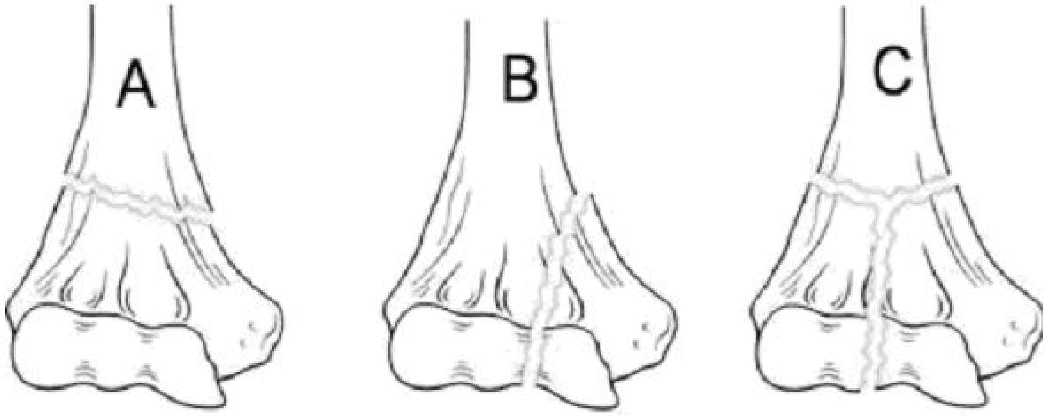

Figure 3. Types of distal humerus fracture(SINGH, 2009).

Surgery for a distal humerus fracture typically involves putting the pieces of the fractured bone back where they belong. Metal implants ð such as plates and screws ð are used to hold things in place until the bone is fully healed. In this work is assumed a simple fixation method using only pins, and two configurations are tested: Two parallel pins and two orthogonal pins (Figure 4).

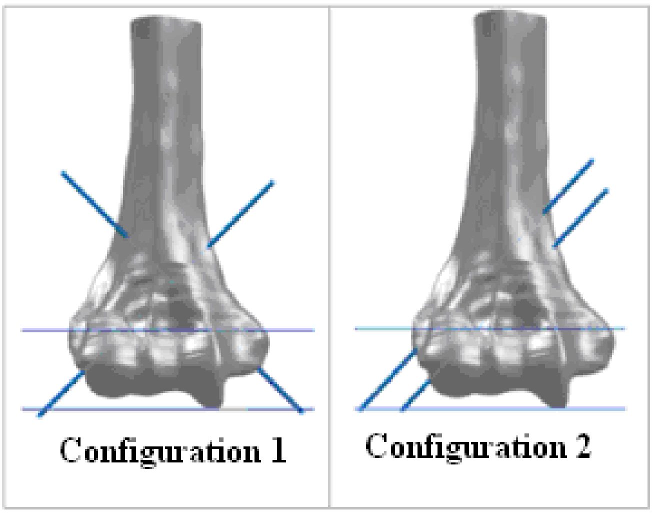

Figure 4. Types of fixation methods simulated (Rocha, 2011).

2.2 - Description of the Model

To simulate this test it was used the Altair Hyperworks 10 solution package. From this solution package the test used the HyperMesh software as a pre-processor to build the finite element models, the Abaqus 6 software as a solver and the HyperView software as a pos-processor (ALTAIR, 2009). The first step was the creation of the finite element mesh, to this we use a DWG model of a Humerus bone show in Figure 5. Since the fracture analyzed was located only at the bottom of the bone, it was cut the upper part of the bone geometry to reduce the size of the finite element model. Also to simulate the fracture the bone was cut in the location shown as a solid line in figure 5.

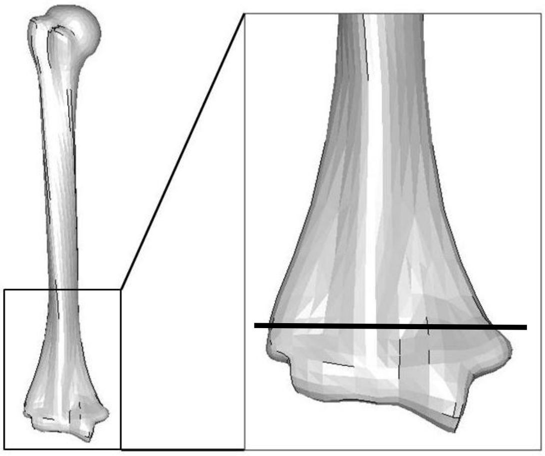

Figure 5. CAD geometry of the bone.

Given the geometry of the bone it was decided that the best element type to represent it would be 3D tetrahedral elements, this kind elements are best used to represent irregular geometries like a bone. Since it was not analyzed the stress in the bone but only in the pins, it was decided to keep the elements in a first order formulation with only 4 nodes to simplify the model and reduce calculation time.

One particular of this model is that, since each configuration has different holes for the pins, it was not possible to use the same mesh for all tests. This could lead to errors in the results by make a comparison of models with different contour conditions. To help minimize these errors it was first created a 2D mesh composed by elements with 3 and 4 nodes and a medium size of 2mm to represent the upper and lower parts of the bone. This 2D mesh was kept as the base model and at each configuration only the location of the roles were changed before the generation of the 3D mesh, also at the time of the generation of the mesh all models use the same software parameters that are: optimize mesh quality and keep the 3D elements at the same size of the 2D basic mesh. One variation of 50% in size of the elements was allowed to facilitate the mesh generation.

The pins used were all identical cylindrical pins, with a diameter of 3mm and a length of 100mm. The pins were represented with hexahedral elements since they have a regular geometry. Hexahedral elements produce better results than tetrahedral but don`t adapt very well in irregular geometries.

Once the mesh of all components was finished, we start building the model. To this test the lower part of the bone was fixed in all degrees of freedom by a rigid element. The upper part also was fixated by a rigid element, but only the translation degrees of freedom were restricted. This part was let free to rotate. As shown in WILLIAMS et al (2010), the elbow joint could suffer torques in the order of 100N/m, so it was decided to use this value as the contour condition of the model and apply it to the upper part of the bone in the Z direction.

Another definition of the model was that the pins would be fixed in relation to the bone, so the contact used was tied. It means that the nodes of the pins in contact with the bone would not suffer relative displacement. The contact of the two parts of the bone was not tied it was let free and receive a friction value to simulate the fracture.

The material properties used in the bone model were taken from an example of the HyperWorks software and the titanium properties (NORTON, 2004). These properties are shown in table 1:

TABLE 1. Results of displacement and Von Mises tension for the pin configurations

MATERIAL	DENSITY [ton/mm³]	E [GPa]	NU	Yield Point [MPa]
Titanium	4.54×10^{-9}	110.316	0.3	1138
Bone	7.70×10^{-12}	207	0.3	-

3. RESULTS

Only the bone and the pins were considerate in those models, any other variable was not included in order to study only the contribution of those parameters. The models are shown in Figure 6.

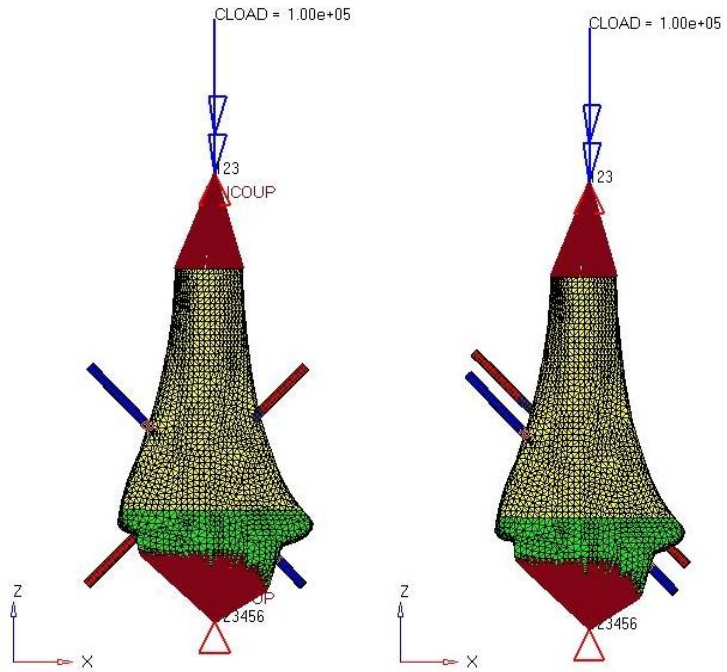

Figure 6. Schematic of the finite element models: Configurations 1 and 2.

With the models ready, we set the parameters of the analysis. It was a static analysis and the parameter of nonlinearity geometric was considerate. As outputs it was requested the displacement of the nodes and the Von Mises stress of the elements. Using this outputs it was determinate the better configuration suited to keep the bones in place and the configuration that causes less stress in the fixation pins.

When the Abaqus solver finished the calculations, the results were opened in the HyperView pos-processor. In this software it was collected the displacement results in two points in each model: one at the top of the model and one at the fracture region. Those points were choose because they were the points of maximum displacement of the models. Since the displacement output serves to demonstrate the configuration`s capacity to keep the bone stable the measurements were made only at the bones and not at the pins. To the Von Mises stress output only the pins were considerate since the objective of the test is to find the configuration that puts less stress in the pins. The results are shown bellow in figures 7 and 8:

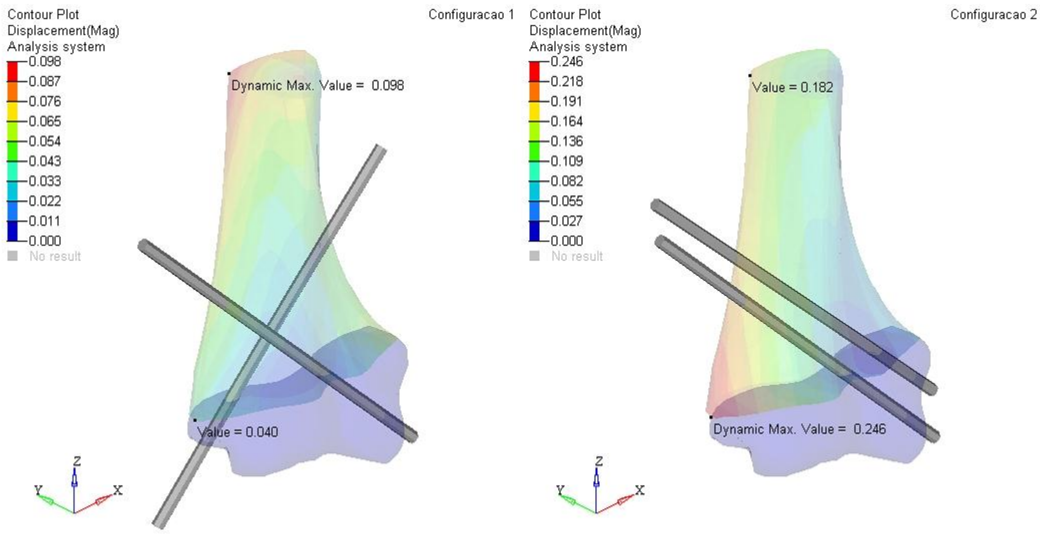

Figure 7. Displacement results for configurations 1 and 2.

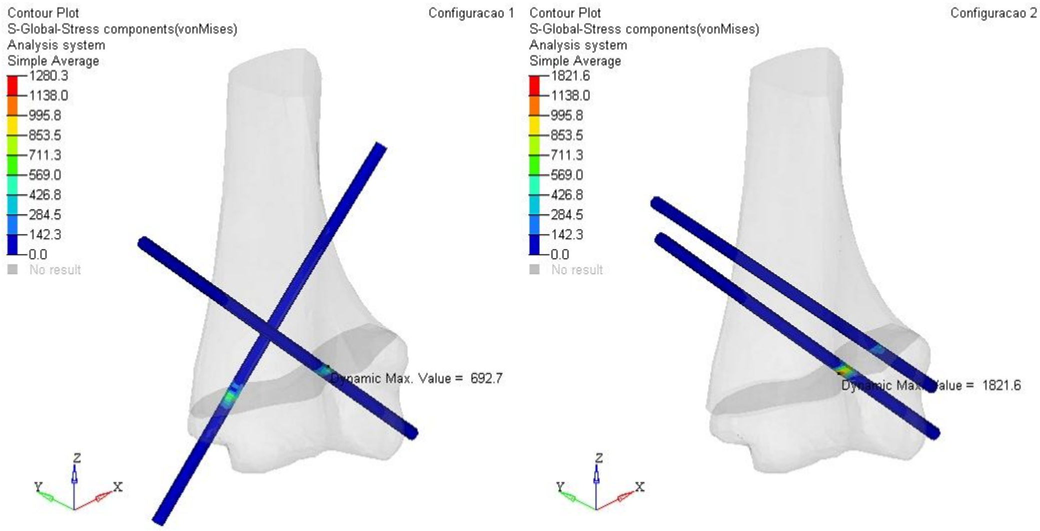

Figure 8. Von Mises stress results for configurations 1 and 2.

The Table 2 presents the results for the configurations evaluated in this study. The results shown that configuration 1 have a smallest displacement between all the evaluated methods and suffer the less stress. In addition, shows that the pins in configuration 2 achieved a stress level superior to the yield point of the material. This situations would damage the pins in a real surgery.

TABLE 2. Results of displacement and Von Mises tension for the four pin configurations

CONFIGURATION	DISPLACEMENT SUPERIOR POINT [mm]	DISPLACEMENT INFERIOR POINT [mm]	VON MISES [MPa]
Configuration 1	0.098	0.040	692.7
Configuration 2	0.182	0.246	1821.6

4. CONCLUSION

The models for two different configurations of fixation were created and simulated. The results show that configurations with more pins and pins in orthogonal positions have better results to fixate a bone fracture. The configuration 1 generate the least stress to the pins and is safely bellow the Yield point. The configuration 1 show that is better than configuration 2 to keep the fracture in place and facilitate the cure of the patient in a real surgery.

These tests proves that finite element analysis and mechanical engineering can be used as tools to help professionals of medicine to take better decisions in their field of work.

5. REFERENCES

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6. RESPONSIBILITY NOTICE

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