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COMPARATIVE ANALYSIS OF THE THREE NEW DESIGNS OF TIBIAL NAILS WHICH ELIMINATE THE USE OF ORTHOPEDIC SCREWS

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Abstract: *The idea to design a tibial nail which eliminate the use of orthopedic screws was given by the study of surgical techniques imposed by the classical tibial nails. Classical nails had some important disadvantages as the difficulty of manipulation and positioning in the bone and, in the same time, the complicate orientation and displacement of the distal screws using the nail guide. Also, all these operations can give failures or/and wrong holes in the bone which can make tibia more breakable. In the same time, all these extra-operations can increase the surgical operation time with unpredictable effects for the fixation of the fracture. All these three design of the tibial nail proposed by our multi-disciplinary team have one single principle, different as the classical nails: the attachment of the nail to the bone is made in the medullary tibial channel using metallic components.*
Keywords: *tibial fracture, tibial nail, virtual bones, biomechanics, virtual prototyping*

1. INTRODUCTION

Fixation is the process which the fragments are fixed in anatomical position and maintained in this position until consolidation using metal implants or other. It should be noted that the position must be anatomic for the fracture. Sometimes the fixation is made, for example in the case of osteotomies where do not achieve anatomic reduction of the fracture, but the contrary is aimed at modifying bone anatomy.
Biomechanics fixation is the fixation after which the used material takes over the forces that occur in fracture focus to achieve consolidation. After a biomechanical osteosynthesis without a cast immobilization, therefore recovery is much better and faster (Figure 1) [1].

Figure 1: Biomechanical fixation

Sometimes a cast immobilization is necessary because tasks can occur in the outbreak of fracture can overcome strength of materials used, or their points of attachment to bone, causing new fractures in these areas, or rupture of osteosynthesis material (Figure 2).


Figure 2: New fractures or rupture of osteosynthesis material

For intramedullary are used fixation rigid intramedullary nails in shaft fractures of the long bones. Can be used two techniques of osteosynthesis with open center or closed center. Unlocked-rigid nails are used in the cases of necominutive shaft fractures when the fracture focus crosses the narrow space of the medullary chanel, when are removed the forces on both sides, having a well controlled rotation. Locked-rigid nails are used when medullary chanel is wider at one pieces (Figure 3).

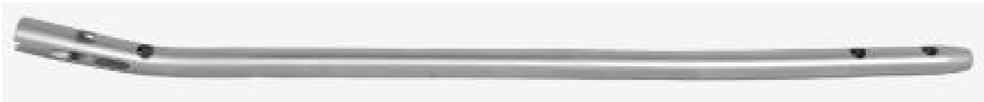
Figure 3: Rigid nail

2. RIGID NAIL USING CLASSICAL FIXATION

On model of tibia obtained by tomography and CAD three-dimensional reconstruction section by section was adapted a rigid nail caught by screws orthopedic on bone fragments [1], [2], [3]. Considered, in a first phase that after fracturing tibia were obtained two bone fragments (Figure 4).

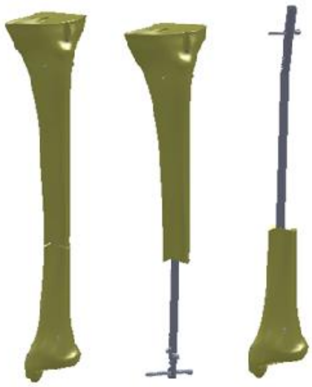
Figure 4: Virtual bone fixation using a classic rigid nail

Virtual rigid nail model was obtained by direct revealing on a real rod with diameter 12 mm [2] (Figure 5).

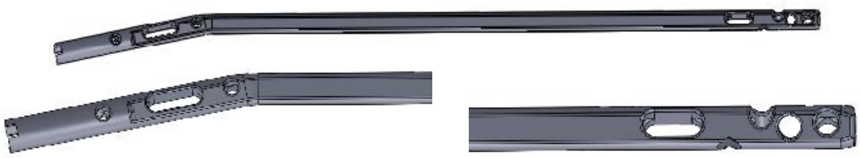
Figure 5: 3D model of classical nail (3 views)

In the same way was obtained the virtual model of the orthopedic screw [2] (Figure 6).


Figure 6: 3D model of classical orthopedic screw (2 views)

Surgical installing of that nail is complicated, requiring the use of a guide to getting holes in the bone, which weakens the resistance, and thus, get effect more or less predictable in healing and tibial fixation (Figure 7).

Figure 7: Use the guide for drilling bone

3. MODEL NO.1: NAIL WITH ARMS FOR INTRAMEDULLARY FIXATION USING RACK-GEAR MECHANISM

All these three design of the tibial nail proposed by our multi-disciplinary team have one single principle, different as the classical nails: the attachment of the nail to the bone is made in the medullary tibial channel using metallic components. The main movement was given by the surgical operator by some special screw keys and the rotation was transmitted thru a universal joint over the bent of the nail (Figure 8).

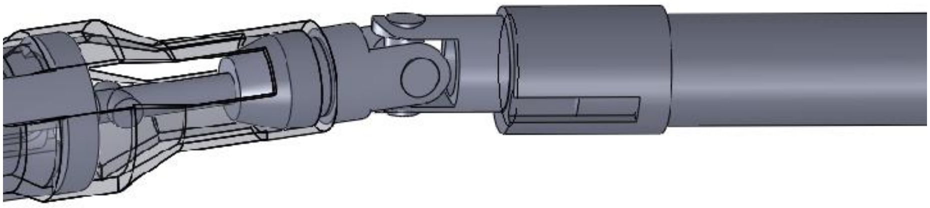

Figure 8: The universal joint transmits the movement to the all mechanisms of the tibial nail

This kind of transmission of motion is common to all three types of proposed nails designs. Also, all three designs have the fixation systems placed at the ends of the nail.
At the first design (Figure 9), the inner rotation was transformed to plannar translation using a rack-pinion mechanism.

Figure 9: The first model of the tibial nail

In that case, the rack has, in the same time, a rotational and a translation movement driven by a nut-screw mechanism. In this first design, the final movement of planar translation was transferred to the three arms which assure the fixation in the medullary channel (Figure 10).

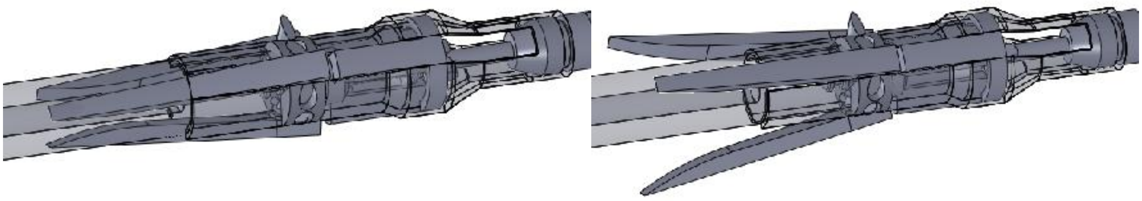

Figure 10: The main mechanism of the arms

The same mechanism was used in the other end of the nail (Figure 11).

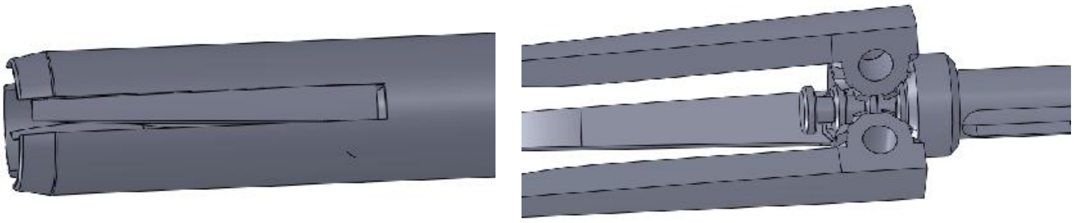

Figure 10: The three arms mechanism used at the end of the nail

This model was virtual-tested using finite element method for a reaction intramedullary force F=500N [2], [3], [4]. The results of the static simulation are presented in Figure 11.

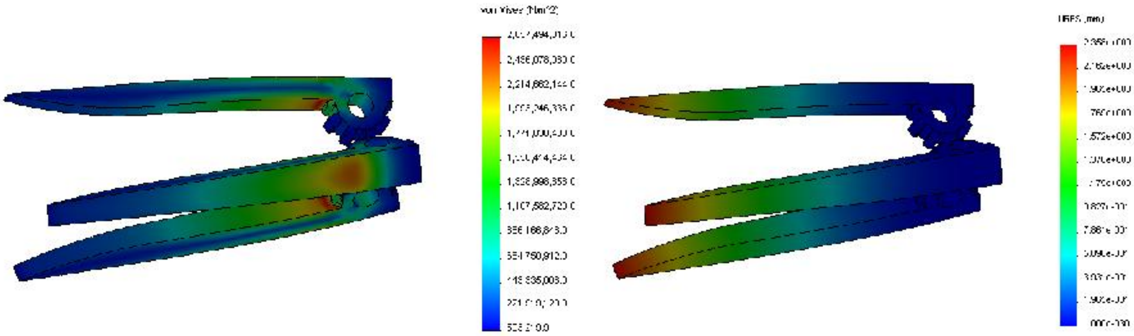

Figure 11: The stress and displacement maps fort the FEA simulation for the first model of the nail

4. MODEL NO.2: NAIL WITH ARMS FOR INTRAMEDULLARY FIXATION USING PLANAR BAR MECHANISM

The second design had almost the same kind of rotation and translation driven by special screw keys thru universal joint which transfer the movement over the bent part of the nail (Figure 12). In the same time, a cable mechanism auctioned by another screw key, assure the alternated transfer of the movement to the two fixation mechanisms placed at the ends of the nail (Figure 13). The fixation was assured by bar mechanism ended with claws, auctioned by a translational movement obtained from rotation by a nut-screw mechanism (Figure 14).

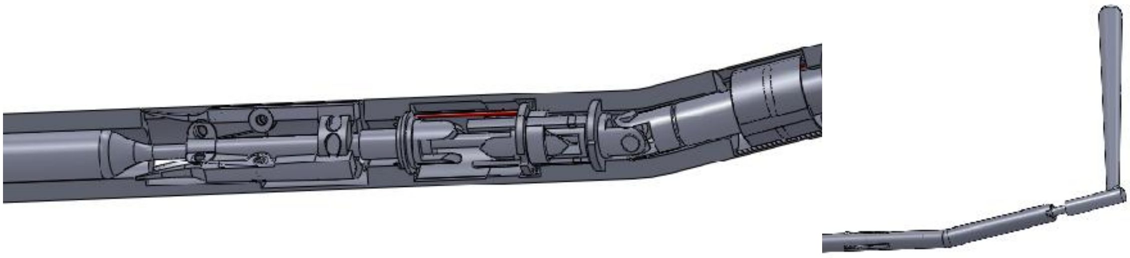

Figure 12: The movement given by special screw keys transferred over the bent part of the nail

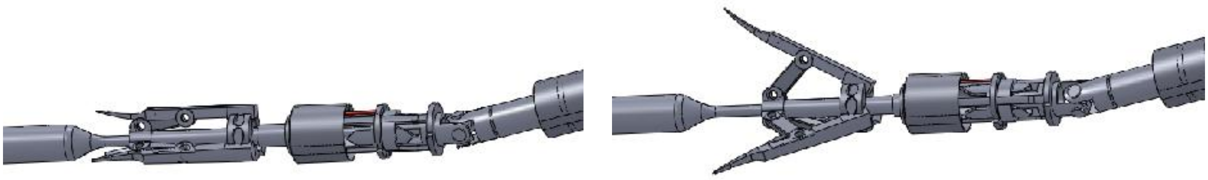

Figure 13: The alternated transfer of the movement mechanisms to the two fixation bar mechanisms placed at the ends of the nail

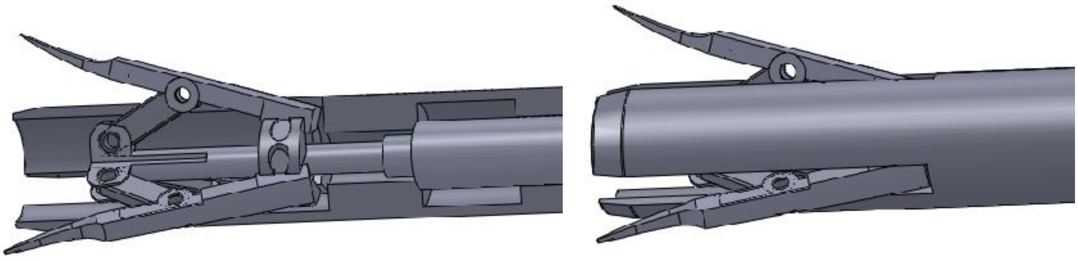

Figure 14: The end bar mechanism

This model was virtual-tested using finite element method for a reaction intramedullary force F=500N [2], [3], [4]. The results of the static simulation are presented in Figure 15.

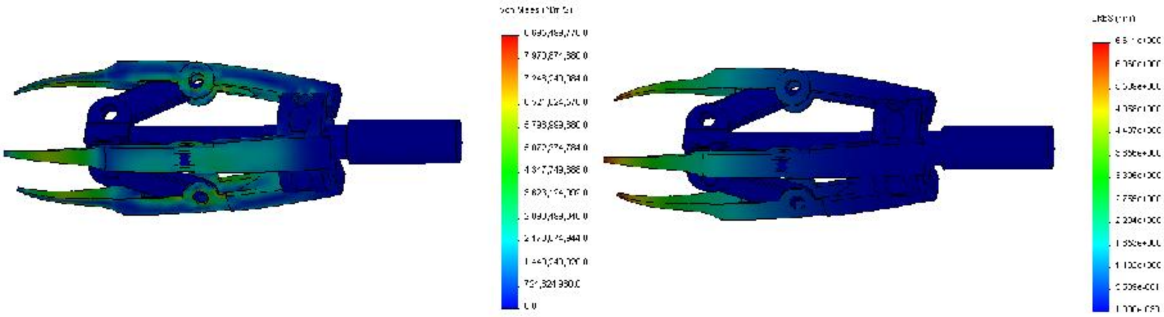

Figure 15: The stress and displacement maps fort the FEA simulation for the second model of the nail

5. MODEL NO.3: TIBIAL NAIL WITH MOVEMENT SCREWS FOR INTRAMEDULLARY FIXATION

The last nail design was characterized by the main auction mechanism made by bevel gears. There are two such bevel gears mechanisms in the two ends of the nail. The main rotational movement is transferred to the bevel gears which had a nut-screw mechanism for the displacement of some four orthopedic screws (Figure 16). In the same time, the screws have rotational and translational movement, which assure the screwing in the bone and the fixation in the medullary channel.

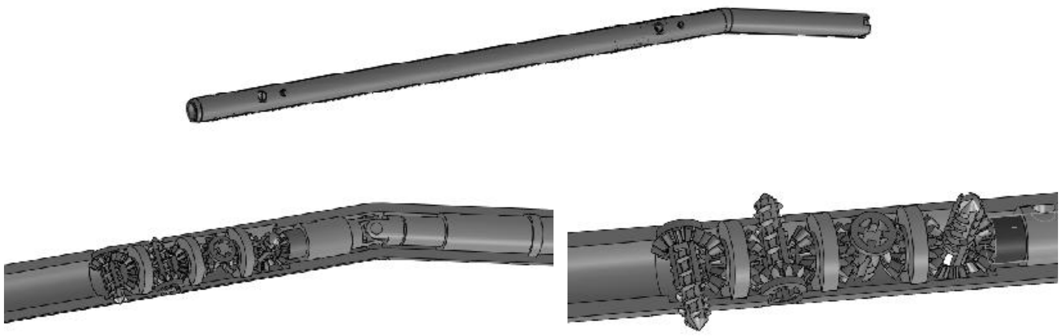

Figure 16: The tibial nail model using movement screws

This model was virtual-tested using finite element method for a reaction intramedullary torque T=2.5 Nm necessary to penetrate the bone [2], [3], [4]. The results of the static simulation are presented in Figure 17.

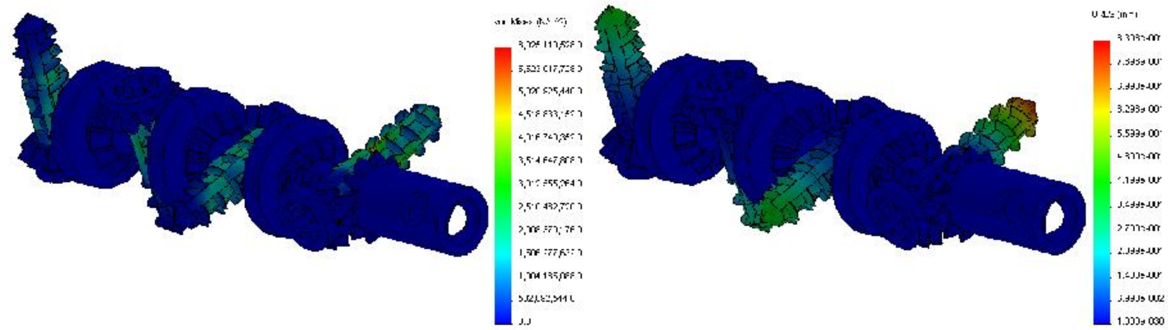

Figure 17: The stress and displacement maps fort the FEA simulation for the third model of the nail

6. CONCLUSIONS

Analyzing the dynamic stress, strain and displacement maps for all three tibial nail models were extracted next conclusions:

- In all three models the fixation was obtained by the tibia bone penetration. From this point of view, the third model allows a normal penetration in the intramedullary canal;
- First model and the second allow penetration of the tibial bone under an acute angle. For this reason, fixing arms of the first two models presented a very much bending;
- In the third model was used penetration screws with the same shape as orthopedic screws, it provides a better fit in the bone tested over several decades;
- Analysis of the three models can become full if using a system of forces and moments obtained by simulating the kinematics of human walking;
- a combined study supposed a close cooperation between many field researchers as engineering and medical specialist;
- an entire and complete analysis can not be possible without CAD, FEA and kinematic simulation software.

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