Finite Element Analysis of External Ilizarov Ring and Hybrid Fixators

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Abstract: ***The mechanical characteristics of an external fixator determines the biomechanical environment of a fracture , osteotomy or non-union treated by the external fixator Two main categories of fixators are in popular use. The more conventional type (e.g. hybrid), The second type of circular or semicircular fixator e.g., ilizarov) relies on smooth , non threaded Kirschner wires of small diameter (1.5mm to 1.8mm) under tension to provide the stability needed. Biomechanically, not only are the principles different but also, the biomechanical environment of fractures by the two system is significantly different .Using Ansys Work Bench 10 the Ilizarov, hybrid1and hybrid2 were modeled and it was found that the mechanical properties ilizarov was better than the hybrid fixators.***

Keywords: Ilizarov, FEA, Hybrid, Kirschner wires, Biomechanics

1. Introduction

Limb amputation constitute one of the mast devasting consequences of wars , natural disasters and terrorists attacks .Among victims affected by explosive injuries in liberated Kuwait between March and December of 1991 ,26.9% required amputation During mine clearance,59% of the injuries resulted in multiple fractures, with an overall amputation rate of 30%. Circular external fixation using thin tensioned wires had has increasing popularity over the past decade gaining recognition for its advantages in fracture healing, limb lengthening and deformity correction. Those advantages include better tolerance of thin wires by bony and soft tissues, and stable , but not rigid, fixation of bone fragments promoting axial micromotion during weight bearing, based on clinical experience and numerical biomechanical[4] studies m the optimal stabilization of bone fragments within an external circular device is achieved through a two level right angles [1,2].the current paper presents a model Comparison of the mechanical performance of different types of external fixators-circular and hybrid . The model uses ANSYS WORK BENCH 10 .the results suggested that the stability of fixation of the illizarov is better than the hybrid1 and hybrid 2 fixator.

2. Methods

Finite Element Analysis of the mechanical properties of ilizarov, hybrid1 and hybrid 2 .The material for all the components of both fixators is assumed to be elastic, isotropic, continuous, and uniform. The material characteristics were taken from the specification of stainless steel X18H10T [18]; modules of normal elasticity -190 GPA; density -7800kg/m^3; ultimate stress -600Mpa; yield strength -200Mpa. Material characteristics of the compact bone were: modules of normal elasticity -16.2Mpa; density-2000kg/m^3 ultimate strength -10Mpa [19].Ultimate strength -170Mpa. To simplify calculations, the Poisson's ratio for all components was taken to be 0.3 .A three dimensional model of the human tibia was created using Ansys work bench 10 a gap of 50mm was generated in the middle of the virtual, model to simulate a bone fracture .Both distal and proximal model were fixed in the models of the ilizarov, hybrid1and hybrid2 fixators

3. Modeling of the ilizarov, hybrid1 and hybrid 2 fixators

A model of the ilizarov, hybrid1 and hybrid 2 fixators were created using Ansys work bench 10 .Three configurations were considered for finite element analysis ,4 ring ilizarov fixator , hybrid fixator 1 , hybrid fixator 2 . The following configurations considered are;

1) 4 rings fixators/1.8mm wires/ wire tension 90kgs /wire angle 90^o/90^o
2) 4 rings fixator /shanz screw/1.8mm wires /wire tension 90kgs /wire angle 90^o/90^o
3) 4 rings fixator /shanz screw/1.8mm wires /wire tension 90kgs /wire angle 30^o/30^o

The mechanical properties and the axial interfragmentary motion are considered for the above fixator. The ability to provide the so called axial interfragmentary motion, whether included in a circular fixator or hybrid fixator changes the mechanical behavior of any known fixator , finite element analysis using Ansys workbench 10 package was used to analyze this effect and interrupt the clinical relevance of the biomechanical data that will be gathered .Modeling[5] of External Load :we assume that the mass of the patient to be 80kg and height to be 180cm. that yields the average load on the tibia is 360N- 1440N.we assume a rigid connection of the elements of the apparatus and their combined deformation as a whole . Stress-strain calculation and deformity of the element of the apparatus were also performed. The above configuration was modeled in Ansys work bench 10 and analyzed in Ansys work bench 10 the loads applied are as follows 360N, 720N, 1080N, 1440N. The load was applied on the top of the tibial bone the axial deformation of the fixator assembly for the three configuration were analyzed in the same way the stresses and strains were also analyzed .Results are shown in fig :2

4. Experimentation

The fig1 shows the standard illizarov[7] fixed on the patient for bone lengthening. The x-ray shows the tissue growth due to the applied load on the bone and the k-wires are tensioned up to 90kgs, carried out by the surgeons and .the data were used for modeling, using the Ansys work bench 10.the figure1 shows the growth of the bone ½ mm per day.

Table 1: Deformation of illizarov fixator

Name of the fixator	*Load 1 360N*	*Load2 720N*	*Load 3 1080N*	*Load 4 1440N*
Ilizarov	10.307	20.614	41.229	51.536
Hybrid 1	10.379	20.758	51.895	41.596
Hybrid 2	1.097	2.195	3.292	5.487

5. Computational Analytical Solution

There are cases in which the ends of the beam are axially fixed and then the transverse load is applied i.e., Kirschner wire in external circular fixators .where the tension in the beam will change after transverse loading .the k-wires which is used for transfixing the bone is taken separately for analysis assuming it as a beam, the maximum deflection is given by

$$y_{\max} = y_1\left(\frac{L}{2}\right) = \frac{P}{2ELK^3}\left[\tan\left(K\frac{L}{2}\right) - K\frac{L}{2}\right]$$

Substituting the values for load and length of the k-wire in the above equation it is found the maximum deflection is found in the case of ilizarov fixator which helps in the interfragmentary[3] motion of the fixator .The IFD is useful of the growth of the bone .
Hybrid 2 fixator .

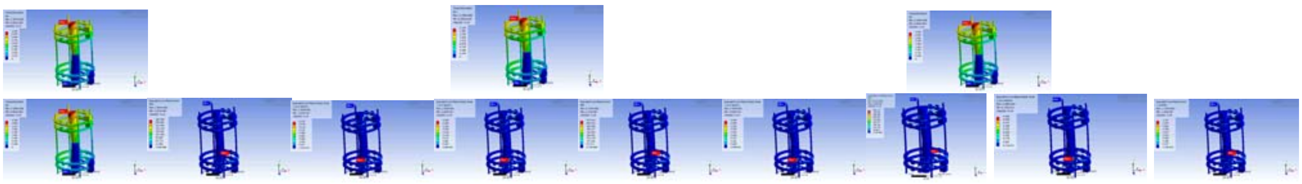

Figure 2: Load on the tibia: 360N to 1440N
Load on the tibia: 720N Load on the Tibia: 1080N Load on the tibia: 1440 N

6. Results

The ilizarov fixator showed better mechanical properties than the other type of fixators, the shanz screw fixator with 90/90 is used ,when more load is required and it also depends on the clinical situation .the 30/30 hybrid is used when the clinical situation arises , the biomechanical properties for the bone growth[6] is not suitable in these fixators. In this respect, measurement of complex interfragmentary movement might be an additional aid in finding appropriate fixations methods in complex osteotomies and thereby optimize the mechanical environment of bone healing.

7. Discussion

The deformation for the various load in the fixator is shown in the table :1At present there is no-well defined system that makes it possible to classify existing external fixator , according to their mechanical performance and clinical use . While their mechanical characteristics are fairly well known for the so-called linear fixators, knowledge of the fixators with both shanz screw and wires for bone fixators is very limited. It is hypothesized that circular fixators and hybrid fixators possess qualitatively different mechanical performance. The purpose of this work is to outline the mechanical performance of a group of currently used circular and hybrid external fixators and axial interfragmentary motion.

The 90/90 cross wire ilizarov fixator showed better mechanical properties than the hybrid 1 and hybrid 2 fixator . the hybrid 2 fixator[10] was least suitable biomechanical fixator because the deformation is more at higher loads the k-wire is strain hardened and it shows the tendency to break which can be inferred from the results obtained in the Ansys results for the deformation of the ilizarov hybrid 2 .the hybrid fixators[9] show a cantilever effect which may deform the bone ,the stresses and strains are very high which may result in the high deformation on the bone lead to fracture of the hard tissues .Deformation shown in table1

8. Future Implications

Hybrid Illizarov[8] fixator can be used for bone fracture and deformity correction, for complicated conditions. The stiffness of the hybrid fixator can be varied, which helps in quick healing of the bone fracture

9. Conclusions

Accordingly it is reasonable to suggest the following hypothesis 1.Cyclic axial micromotion is beneficial to fracture healing 2.Translational shear at the fracture site is deleterious to fracture healing .if the above hypothesis are valid, then we can speculate which fixation provides a more optimal biomechanical environment.

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