Design and Analysis of Circular External Fixation for Human Leg

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Abstract

In this wok predetermined to analyze the design of circular external fixation system for bone joining. It is a fixation system where threaded pins are connecting in the bone. This internal wires pass through the cortex on either side of the medulla space, and only a few 'mm' of the internal wire tip should protrudes through the distal cortex. The usual complications of this fixation system are loosening of the wires. These internal rods deform and in turn distorts the bone. To avoid the stress on the bone, the fixation technique is analyzed and the mechanical behavior of the circular fixation device is developed. The stresses related is the present fixation and the stress after redesign are to be studied. The aluminum material is used for connecting rod, wire bolt, nut, bolt, internal wire. Nowadays, they are using stainless steel as a material and it can create high weight, high pain, and high cure time. So the carbon fiber material is used for this fixation, and it can create less weight, less pain, and less cure time. The new design and materials of fixation will in our analysis can be used carbon fixation at a cone it will decrease the stress, strain of the body and weight also decreased. It will increase comfortably of the body, while walking. The fixation is designed using Solid edge V20 and analyzed using ANSYS 16.0.

Keywords: Circular Fixator, Bone, Deformation, Load, Solid Edge V20, ANSYS 16.0

I. Introduction

The external fixator is a wire circular frame device formulated by Gavriil Ilizarov in Kurgan, Siberia in 1952. The method relies on the basic bio-mechanical principle of axial compressive loads and micro movement arouse biological bone bridging of the fracture gap. This mechanism depends on wire tension. This Ilizarov method was not deliver to the west until 1981. The Ilizarov method is antiseptic established in fracture management, limb salvage and deformity correction. External fixation is a surgical treatment where in rods are screwed into bone and exit the body to beat connected to a stabilizing structure on the outside of the body. It is an different to internal fixation, where the components used to provide stability are positioned absolutely within the patient's body. It is used to maintain bone and soft ornament at a distance from the operative or injury focus. They provide unobstructed access to the relevant skeletal and soft ornament structures for their initial assessment and also for secondary interventions needed to restore bony continuity and a functional soft tissue cover.

Fig. 1.1: Model of human leg bone with Fixation

The circular external fixation system consisting of tensioned wires attached to a modular circular frame. The device is used for connecting fractured bone segments with increasing applications in treatment of skeletal deformities and trauma, as well as limb lengthening. The main advantages of the circular external fixation is a high degree of patient mobility at an early stage of treatment, influencing optimal bone regeneration through functional activity of the muscles and the joints of the limb.

II. LITERATURE REVIEW

Jai Ganesh. V, et al (2015) was developed the model the paper was intended to analysis the design of circular external fixator system for bone union. It was a fixator system where threaded pins were anchored in the bone. These pins pass through the cortex on either side of the medullary space, and only a few 'mm' of the pin tip should protrudes through the distal cortex and to avoid the stress on the bone. It was used when the load carried by the patient was very high and the load was acting at particular area of the bone. S. K. Kourkoulis, et al (2010) was presented the construction of a devoted numerical model of the standard Ilizarov fixator that will license a detailed parametric investigation of various factors affecting the effectiveness of the technique. Mechanical test of a standard Ilizarov frame were decided under axial and torsional loads. To exterminate the pretension loss due to wire slippage metal nuts with M1.8 thread were manufactured. The model construction simulated precisely all the geometrical details of the experimental modal, the load application mode (axial and torsional) and the mechanical characteristics of the materials used to assemble the frame. Compression of the predictions of the model with the respective experimental data yields excellent agreement for the case of tension and rather satisfactory one for torsion. Ozgur Verim. M, et al (2017) was the analyzed biomechanical optimization of the newly designed circular external fixator system, used in the orthopaedics surgery, that was capable of uninterrupted compression at the fracture line. The stress on the bone was transferred to the rings by Kirschner wires on the fixator system, thus they took active role in load carrying. When the stresses on the lower and upper surfaces of the fracture line were examined, an increase in distribution of stress from posterior to anterior was observed. The maximum normal stress on the upper and lower surfaces of the fracture line was found as 0.83 and 0.81 MPa, respectively. According to the result of the evaluation, the effectiveness of the parameters, in descending order, were the pre-loading, the spring coefficient, the wire diameter and the angle between wires, respectively. C. Tejwani, et al (2007) have been developed, , hybrid external fixators, using a combination of pin-bar and wire-ring systems, extend the applications of external fixation. Inattentive of the type of system used, the same principles apply regarding pin and wire insertion, bone-wire interface pins, clamps, rings, and sidebars. it was important to take into account the advantages and disadvantages of each system available, the extent of soft tissue damage, and the nature of the fracture or bony realignment that was to be addressed in order to most effectively treat the limb and benefit the patient. Karel Frydrysek, et al (2012) were designed the external fixators for treatment of pelvis and acetabulum fractures are evident. Therefore, all results could not be published in this paper due to discretion reasons. Hence ,the new designs and materials of fixators will satisfy the ambitious demands of modern traumatology, surgery and economics. It focused on the solution of external fixator for treatment of open and complicated fractures of limbs too. Simone Riganti, et al (2019) were presented with a complex rigid foot deformity, the most common diagnosis was arthrogryposis and idiopathic club foot sequelae. It had been treated with previous surgery consisting of capsular release, tendon lengthening or other bone procedures with unsatisfactory results. We attended 1 problem (toes flexion which did not require any treatment), and 3 obstacles: 2 metatarsophalangeal joint dislocation (which required tenotomy of the flexor tendons and temporary arthrodesis by pinning), and 1 Incorporation delay (treated with autologous bone graft from the iliac crest) which, however, occurred at a proximal tibial osteotomy site and was not related to foot deformity correction. Koji Nozaka, et al (2020) were associated with periprosthetic fractures in elderly patients. Double-plate or revision surgery were largely unwanted and had high risks associated with insensitivity. Circular external fixation was a feasible and effective treatment option because it provides stable fixation, prompt postoperative mobilization, and has no major complications, especially in elderly patients who are treated for periprosthetic fractures. Circular external fixation was a safe and reliable method for periprosthetic fractures around the knee in elderly patients. Filip Tomanec, et al (2018) has been created the weight of fixator was reduced by 63% in contrast with standard performance and composite fixator also reduced the volume of metal components in constructions. The results show that the overall weight has been reduced significantly, whereas the results of analysis exhibit sufficient strength of external fixator. Nevertheless, the design of fixator and especially the construction of supporting rings can be improved in order to improve safety factor of the final fixator model. A M Udosen, et al (2006) were highlighted the usefulness of external fixation devices and the need to encourage its use in the developing world. It also stresses the embarrassment come upon in a Nigerian teaching hospital. A call is made to all surgeons particularly those in rural areas to make use of this simple appliances after due training. Government should provides the hospitals with these tools and impassion the fabrication of such in our environment. Ana Martins Amaro, et al (2020) were discussed the problems of fixation: (1) increasing the distance between the bone and external fixation body from 50 mm to 70 mm increases the percentage of the load passing through the callus by approximately 6% to 11%. Nevertheless, increasing this distance from 70 mm to 90 mm does not significantly change load share ratios; (2) the inter fragmentary deformation at a distance between axes of 50 mm is more sensitive to changes of the intensity of loading than the other two distances; (3) the predicted cell load values correlated well with the experimental results, but the difference of the clamp-rail clearances between the numerical and experimental models had a negative influence on results agreement; (4) the clamp-rail clearances are responsible for the locking stiffness of the LRS external fixation and depending on the fixation construction its value changes from 12.92 N/mm to 22.63 N/mm; and (5) highest values of the locking stiffness are associated with less load passing to the callus bone, due to the higher blocking effect of free clamp. Michael P, et al (2005) have been described and used for sustained portable traction, some allowing active and passive joint motion, and external fixation provides a useful alternative. An external fixation overpass a joint can often be removed within 3 or 4 weeks, and exercises can be initiated. Another at the proximal interchangeable joint is a pivoted external fixation that can allow immediate active movement. Lewis E, et al (2015) have been created External fixation may be effectively used to reduce and stabilize distal femoral metaphysical fractures. The best situations for the use of external fixation for this injury were in children who have sustained poly trauma, an open fracture, or a floating knee. In cases of poly-trauma with multiple fractures, abdominal injury, or head injury, stabilizing the fracture with an external fixation allows the child to be transported for diagnostic studies or operative procedures. In determined comatose children, external fixation provides stability of the fracture when spasticity ensues. David J, et al (2009) were developed the bio-mechanical requirements of external fixation for fractures of the distal radius have not been ascertained because until more recently, the magnitude and direction of the physiological loads on the distal radius were changes in volume and unknown. Work by Rikli and colleagues12 has shed new light on this point, however. Using a new capacitive pressure-sensory device, these investigators measured the in vivo dynamic intra-articular pressures under local anesthesia in the radio ulnocarpal joint of a healthy volunteer. Melissa Thacker, et al (2020) have been evolved primarily to care for initial management of complex open or severely comminuted, unstable fractures that are most often the result of high-energy injury or multiple trauma. In particular, external fixation was used for severe metaphyseal fractures, severe intraarticular fractures, when there has been nonunion, in cases of substantial bone loss with allograft, and for fractures in osteoporotic bone. They are particularly useful when fracture disrupts pelvic stability. Pins are placed into bone on either side of the fracture and then clamped onto lightweight rods in an external frame. The external frame can be a single rod, a set of articulated rods that cross the joint axis, circumferential, or a combination of these options. Andrew Howard, et al (2009) was presented a greater risk for re-fracture than other treatment methods because the stiff frame may delay consolidation and then is removed abruptly. The true exposed for re fracture is not known and may be no greater with external fixation than with other means. A retrospective comparative study of 66 femoral fractures treated with external fixation found 8 re-fractures (12%) and found that the risk for re- fracture was 33% if fewer than 3 cortices had bridging callus at the time of fixation removal compared with 4% if 3 or 4 cortices demonstrated bridging callus.

III. MATERIAL SELECTION

We are selected the two different types of materials are as follows,
- ALUMINIUM (6061-T6)
- CARBON FIBER (PCM-Polycarbonate Matrices)

A. Aluminium (6061- T6)

Aluminium alloy 6061 is a midway to high strength heat-cured alloy with a strength higher than 6005A. It has very good corrosion resistance and very good weldability despite decreased strength in the weld area. It has midway fatigue strength. The T6 declares to the temper or degree of hardness, which is carried out by precipitation hardening. This grade has a good strength-to-weight ratio and is also heat-cured. With good formability and weldability, it is used for engineering and structural applications, boats, furniture, and more.

B. Carbon Fiber

Carbon fibers (otherwise CF, graphite fiber or graphite fibre) are fibers about 5 to 10 micrometers (0.00020–0.00039 in) in diameter and assemble mostly of carbon atoms. Carbon fibers have several taking out including high stiffness, high tensile strength, low weight, high chemical resistance, high temperature tolerance and low thermal expansion. These properties have made carbon fiber very famous in aerospace, civil engineering, military, and motorsports, along with other competition sports. However, they are relatively reasonable when compared with similar fibers, such as glass fibers or plastic fibers.

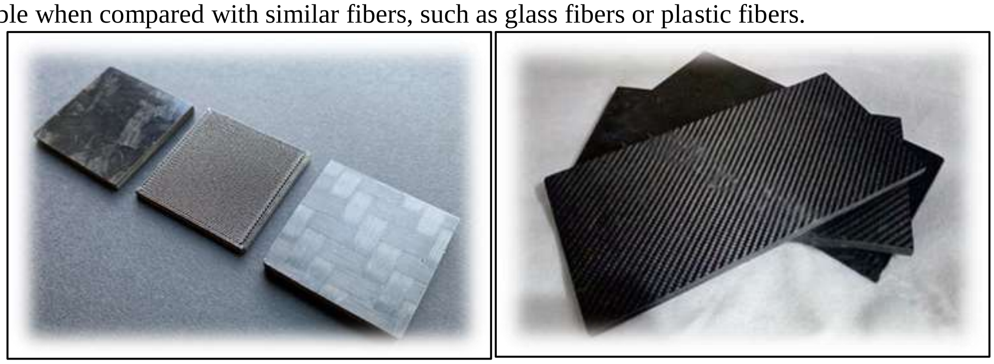

Fig. 3.1: Carbon fiber

IV. DESIGN OF CIRCULAR EXTERNAL FIXATION

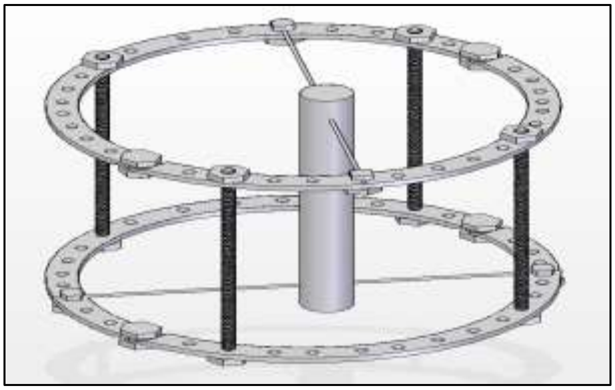

Fig. 4.1: Circular External Fixation

The external fixator is designed and assembled using the solid edge V 20. The circular ring is used to support in external fixation a 36 small holes are drilled on it. Because it is used to alignment of internal wire position on ring. Then the carbon fiber material used in only the circular rings and the ring diameter in 240mm and the small hole diameter in 6mm. This ring is fixed top and bottom of external fixation.

V. ANALYSIS OF CIRCULAR EXTERNAL FIXATION

A. Equivalent (Von-Mises) Stress

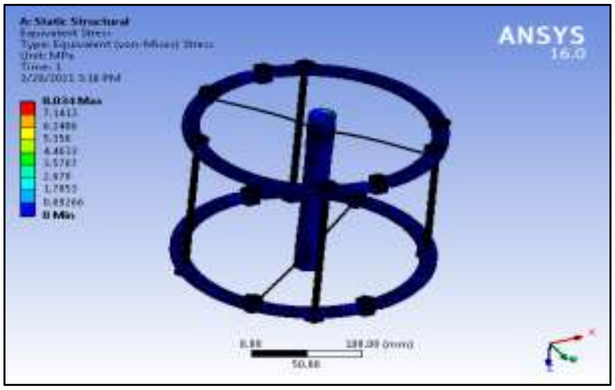

Fig. 5.1: Equivalent (Von-Mises) Stress

The force is applying on fixator the force value is 588.6N (Compression Load ↓). This fixation is analysis the maximum stress is 8.034 MPa by using carbon fiber and aluminium materials. This stress value is very low compared to the stainless steel material analysis value the stress value is 141.311 MPa. So the stress is reducing 94% compare to stainless steel material. So the patient's feels comfortable while walking.

B. Equivalent Elastic Strain

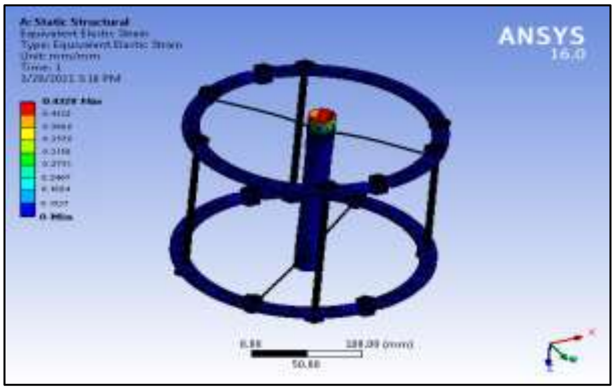

Fig. 5.2: Equivalent Elastic Strain

The force is applying on fixator the force value is 588.6N (Compression Load ↓). The maximum elastic strain value is 0.4328 by using the carbon fiber and aluminium materials are compare to stainless steel material this elastic strain value is minimum and the stainless steel material elastic strain value is 0.462. So no problems to here on fixation for minimum value of elastic strain. It is defiantly safe to uses for fracture bone.

C. Total Deformation

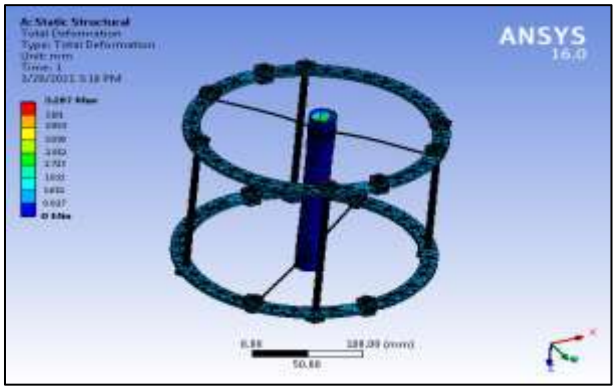

Fig. 5.3: Total Deformation

The Cauchy strain or engineering strain is expressed as the ratio of total deformation to the initial dimension of the material body in which the forces are being applied. The force is applying on fixator the force value is 588.6N (Compression Load ↓). The maximum total deformation value is 3.287 mm by using the carbon fiber and aluminium materials are compare to stainless steel material this deformation value is less. Because less weight materials used for this fixation so the minimum deformation is created here. The minimum deformation is not affect the fixation so that is no problems for uses. Because it can be change in original position after the deformation.

D. Maximum Shear Stress

The Maximum Shear Stress theory states that failure occurs when the maximum shear stress from a combination of principal stresses equals or exceeds the value obtained for the shear stress at yielding in the uniaxial tensile test.

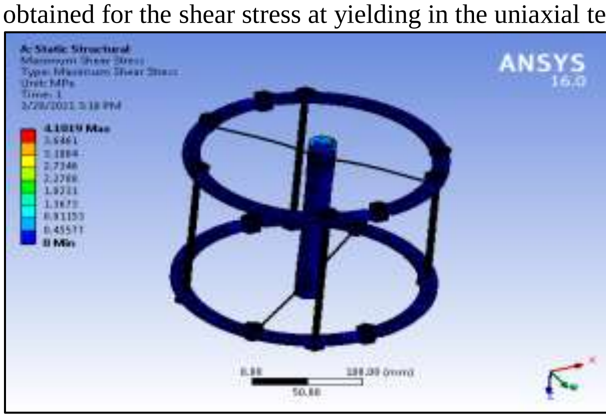

Fig. 5.4: Maximum Shear Stress

The force is applying on fixator the force value is 588.6N (Compression Load ↓). This fixation is analysis the maximum shear stress is 4.1019 MPa by using carbon fiber and aluminium materials. This stress value is very low compared to the stainless steel material analysis value the stress value is 72 MPa. So the Shear stress is reducing 80% compare to stainless steel material. So it is reducing the fracture cure time in the particular fracture area.

Table - 5.1
Analysis Value Comparison

S.No	*Types of Stress*	*Stainless steel (load= 720 N)*	*Composite (aluminium, Carbon fiber) (load= 588.6 N)*
1	*Equivalent (Von-Mises) Stress (MPa)*	*141.311*	*8.034*
2	*Equivalent Elastic Strain*	*0.462*	*0.4328*
3	*Total Deformation (mm)*	*3.446*	*3.287*

VI. CONCLUSION

In this work we have been reduced leg injured people suffered from injury. The internal wire is act simply supported beam in the fixation. This is used when the load carried by the patient is very less and the load is acting at particular area of the bone. This type of material is used to reduced maximum stress in human bone. So the human leg pains are reduced in human leg. The fracture is cure fast by this material used in this fixation and the materials cost is lower than steel material. This fixation is to reduce the total weight of this equipment and also to reduce the equipment cost. The stress is reducing 94% compare to stainless steel material. So the patient's feels comfortably while walking. The strain is reducing 64% compare to stainless steel material and it is reducing the maximum tension in fixation. The total deformation is reducing 74% compare to stainless steel material and it is avoiding the damage of external fixation. It can be change in original position after the deformation. This type of fixation is made by our selection materials it is reduce the maximum stress on bone and cure the fracture in the bone as fast.

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