Reconstruction of Knee Joint by Using 3 Matics and Mimics and Design and Analysis of Knee Joint Plate for Maximum Loading Condition

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ABSTRACT: The mechanical stress determination in human femur bone is of great importance in both research and clinical practice. One of the methods to estimate stress is through finite element modeling. In spite of that, the modeling technique has to be validated by an experimental approach as it is the best tool to access the accuracy of finite element model predictions. However, in the previous studies, this validation has not been carried out extensively due to limited number of studies available and the difficulties of the experiment procedure. The aim of this paper is to develop an experimental method in order to determine the maximum stresses at the surface of the bone prototype under normal loading. An experiment is conducted where load is applied at the femoral head and the maximum stress on the bone surface is determined with the presence of strain gauges. Three-dimensional (3D) printing technology has received great attention in the past decades in both academia and industry because of its advantages such as customized fabrication, low manufacturing cost, and unprecedented capability for complex geometry, and short fabrication period. 3D printing of metals with controllable structures represents a state-of-the-art technology that enables the development of metallic implants for biomedical applications. To develop the CAD model of knee joint we have used the CT scans of the knee joint and developed in the mimic's software. To design the knee joint implants, we have used 3Matics software. From here we can analysis the knee joint and plans the surgical operations. We can manufacture the suitable implant for specific patient requirement so that the surgical time will be reduced. The structural analysis has been performed using Altair inspire Optistruct software for human weight.

Key words: Knee joint, 3 Matics, Mimics, 3D Printing, CT scan, CAD

I. INTRODUCTION

This paper investigates the suitability of using RP technology and associated medical software solutions to transfer 2D Digital Imaging and Communications in Medicine (DICOM) data into 3d Standard Triangle Language (STL) data. This data is then utilized using medical software solutions to manufacture preoperative planning models and customized medical implants for the benefit of patients and surgical planning teams alike. The work also gives an overview of relevant subject matter such as medical scanning, RP, preoperative planning models, customized implants/jigs and biocompatible materials. Case studies are included as a method of illustrating how the different technologies integrate and function to produce tangible successful outcomes that make a significant difference in medical interventions.

Prior to RP the production of medical models of individual patients was very rare due to the difficulty and cost of generating (usually by CNC machining) complex geometry associated with anatomy. Medical implants were manufactured using pressing, forging, machining and casting processes. Unfortunately, due to the limitations of the manufacturing processes this often resulted in bulky, poorly fitting and costly implants. With the introduction of RP technology, these types of problems were solved using the additive manufacturing (AM) or "layer by layer" process. Building intricate geometrical parts suddenly became less problematic and cheaper this helped RP technology gain acceptance by the medical profession.

Production of Anatomical Models from CT Scan Data by JOHN BRENAN

In this paper the latest medical data processing software tools will be used to generate models for preoperative

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planning and also medical training and the results reviewed. A comprehensive literature review in the field has been conducted and publications in the medical scanning, RP, preoperative planning, biomaterials, customized medical implants and jigs are presented and discussed. Several case studies that are particularly pertinent to the trials undertaken by the author have been identified and incorporated into the report and explained in detail in order to illustrate the capability, potential and flexibility of this technology within the medical sector.

Determination of muscle forces acting on the femur and stress analysis by Silke Renner, Technische Universität München

A stress analysis of the femur using the finite element software ANSYS was performed, comparing the biomechanical Pauwels' model and the "Stemmkör per model" in the one-legged stance.

Teaching Biomedical Engineering Design Process and Development Tools to Manufacturing Students

This study presents laboratory development efforts for a rapid prototyping and reverse engineering course taught in this ABET accredited manufacturing engineering program. The main objective of the work is to introduce biomedical design and development processes and associated tools in this manufacturing program. The driving factor is to improve the versatility of the manufacturing engineering students in addition to better marketability of the graduates in this medically oriented geographic region and beyond. The author has been developing physical and software laboratories for his biomedical engineering program. The developed laboratories are to be utilized in the design and manufacturing of biomedical devices and systems course and also included within the scope of the rapid prototyping and reverse engineering course.

Design and Development of an Offset Lightweight Polymeric Orthotic Knee Joint for Polio and Cerebral Palsy Patients BY J.K.CHAKRABORTHY

Polio patients mostly belongs to the poor class of the society and need cheap, light, high functioning orthotic callipers to be able to participate normally in daily functions of life. The concept of drop lock, gravity lock or automatic lock for callipers joint is not a very new subject as it was designed and even commercialized in the past. This design and development work claims priority to the prior calliper joints due to its unique design for injection moulding that can allow changes in function, material, weight and cost. The joint is designed, analyzed, manufactured and trial tested with satisfactory results.

Nano-Materials for Bone Implants BY Garrett Cavanaugh

An increase of geriatric patients requires improved orthopaedic implant technology. Hydroxyapatite is a material naturally found in bone tissue, but the use of synthesized hydroxyapatite in orthopaedic implants is limited because of its poor mechanical properties. The goal of this work is to use nanocrystalline hydroxyapatite and epoxy resin to create composite materials that mimic bone tissue's nano-structure, test their mechanical properties to determine the influence of nanostructure and characterize the failure mechanisms using electron microscopy.

A CT-Based High-Order Finite Element Analysis of the Human Proximal Femur BY CHARLES MILGROM

The prediction of patient-specific proximal femur mechanical response to various load conditions is of major clinical importance in orthopaedics. This paper presents a novel, empirically validated high-order finite element method (FEM) for simulating the bone response to loads. A model of the bone geometry was constructed from a quantitative computerized tomography (QCT) scan using smooth surfaces for both the cortical and trabecular regions. Inhomogeneous isotropic elastic properties were assigned to the finite element model using distinct continuous spatial fields for each region. The Young's modulus was represented as a continuous function computed by a least mean squares method. P-FEMs were used to bind the simulation numerical error and to quantify the modeling assumptions. We validated the FE results with in-vitro experiments on a fresh-frozen femur loaded by a quasi-static force of up to 1500 N at four different angles. We measured the vertical displacement and strains at various locations and investigated the sensitivity of the simulation. Good agreement was found for the displacements, and a fair agreement found in the measured strain in some of the locations. The presented study is a first step toward a reliable p-FEM simulation of human femurs based on QCT data for clinical computer aided decision making.

II. DISPLAYING A 3D REPRESENTATION

- In the vertical 3D toolbar on the right, you can set the visibility of the different calculated 3Ds. This can also be done in the work Management's 3D Objects Tab, by clicking on the glasses.
- Once the 3D image is loaded, different operations are available:
- rotate the model with the button  on the right of the 3D window or moving the mouse pressing the right button;
- select different standard views, like Top, Front, Bottom, by clicking on the button  on the right of the window;

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- zoom with the buttons or Pan with the ;
- change the color of your model and background by clicking the right mouse button and selecting the option "Color";
- The model can also be displayed transparent. To do so, push the Toggle Transparency button . You can switch between different degrees of transparency (high-medium-low- opaque) by clicking the square button in the transparency column of the 3D objects tab.

III. SIMULATION RESULTS

We have applied 55 kg force on the knee joint implant to study the mechanical behaviour of the knee joint plate. The applied load is varying with respect to patient and the thickness of the plate or rod is depend on the size of the fracture and human weight.

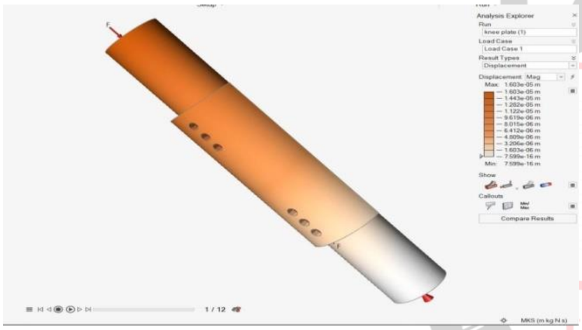


Fig 1 dispalcement of knee plate

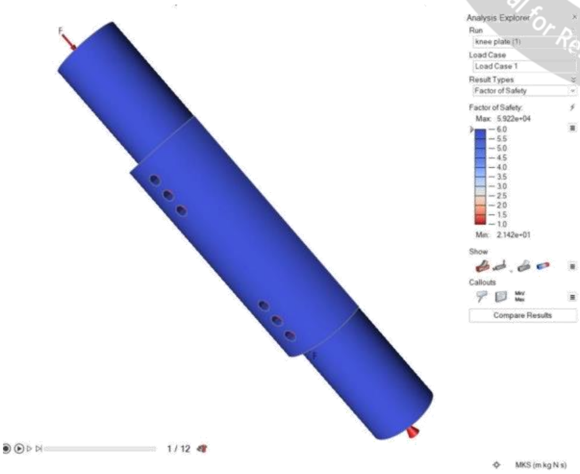


Fig 2 factor of safety of knee plate

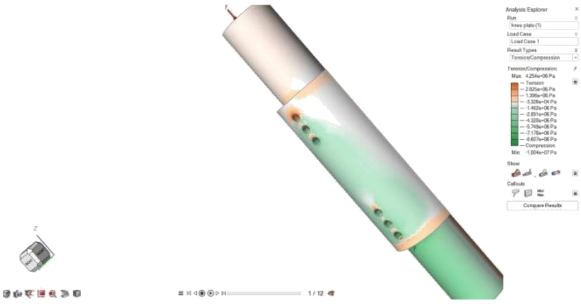


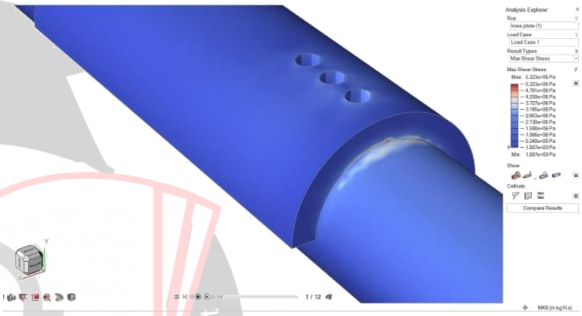
Fig 3 materiak used for knee plate

Parts and Materials

Parts | Material Library | My Materials

Material	E	Nu	Density	Yield Stress	α	λ
Steel (AISI 304)	1.950000E+11Pa	0.290	8.000E+3 kg/m3	215.000E+06 Pa	17.300E-06 /K	16.200E+00 W/(m*K)
Steel (AISI 316)	1.950000E+11Pa	0.290	8.000E+3 kg/m3	205.000E+06 Pa	16.000E-06 /K	16.300E+00 W/(m*K)
Steel (AISI 1015)	2.000000E+11Pa	0.290	7.870E+3 kg/m3	285.000E+06 Pa	11.900E-06 /K	51.900E+00 W/(m*K)
Steel (AISI 1040)	2.000000E+11Pa	0.290	7.850E+3 kg/m3	350.000E+06 Pa	11.300E-06 /K	50.700E+00 W/(m*K)
Steel (AISI 1080)	2.000000E+11Pa	0.290	7.870E+3 kg/m3	380.000E+06 Pa	14.700E-06 /K	48.100E+00 W/(m*K)
Steel (AISI 4130)	2.000000E+11Pa	0.290	7.870E+3 kg/m3	360.000E+06 Pa	13.700E-06 /K	42.700E+00 W/(m*K)
Steel (AISI 4142)	2.000000E+11Pa	0.290	7.870E+3 kg/m3	585.000E+06 Pa	12.200E-06 /K	42.600E+00 W/(m*K)
Aluminum (2024-T3)	7.500000E+10Pa	0.330	2.770E+3 kg/m3	275.800E+06 Pa	22.800E-06 /K	121.000E+00 W/(m*K)
Aluminum (2024-T6/T8)	7.500000E+10Pa	0.330	2.770E+3 kg/m3	275.800E+06 Pa	22.800E-06 /K	151.000E+00 W/(m*K)
Aluminum (6061-T6)	7.500000E+10Pa	0.330	2.700E+3 kg/m3	241.300E+06 Pa	23.500E-06 /K	167.000E+00 W/(m*K)
Aluminum (7075-T6)	7.500000E+10Pa	0.330	2.800E+3 kg/m3	413.700E+06 Pa	23.200E-06 /K	130.000E+00 W/(m*K)

Fig 4 maximum shear stress developed in knee plate



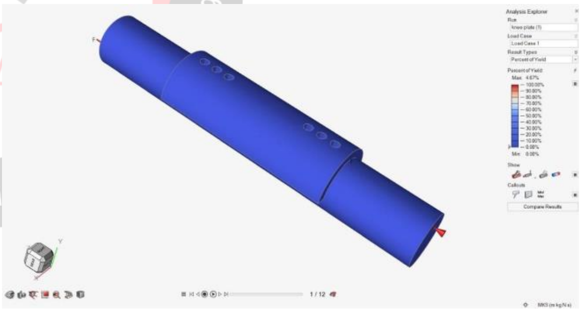


Fig 5 percent of yield developed in knee plate

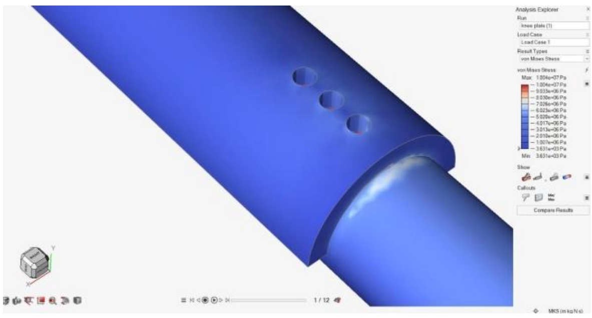


Fig 6 von mises stress developed in knee plate

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IV. CONCLUSION

We have successfully developed the knee joint from the CT scanned data by using mimics software. Hence by generating accurate 3D model of femur bone of patient, diagnostics can be carried out especially for that patient more conveniently. Hence, doctors can see bone model from different view and at different angle because full details can't be gathered from CT scan data. From the prototype doctors can study the fracture very clearly and plan the surgical operation.

Just before biomedical implants doctors used to bend the implant plate and drill the holes during the surgery. We have developed the biomedical implant for specific patient so that we can directly implant the plate in the human body, this will reduce the load on the doctors during the surgery. It will reduce the surgery time. knee joint plate has been studied for structural analysis to study the displacements, stresses, factor of safety, shear stresses over the plate. The knee joint plate studied for the specific patient weight and fracture length. The total weight of the knee joint plate is depending on the type of fracture, length of fracture and patient weight. Depends on the application of biomedical implant the applied for will change.

Finite element method thus makes the stress analysis of complex 3D object simple and more easily understandable which helps in medical field for analysis of bone under loading conditions. It is expected that extensive use of finite element method for analysis of femur using different implant materials and structural arrangements will help in development of new biomedical implant. The analysis of knee plate performed by using Altair inspire. By performing the simulation can say that the plate is under safe condition. the factor of safety of the plate is 5.99.

In future we can develop the implants of different human parts with good life and proper implant design. In future organ 3d printers will be available to replace the human organs directly during the surgeries by using hydrogels, blood cells of specific human parts and scaffolds. Still the scaffold geometry needs to study in the field of bio medical printing process.

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