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FEA Analysis of the Knee Joint, During Knee Flexion Movement

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Abstract: **-- Dimensional model of the knee joint was constructed or built by using "Mimics" software, Only used MRI scan, 2 Dimensional images (DICOM), to create a model of the knee joint. Which only includes Femur and Tibia, for the soft tissues of the knee, require CT scan images, which was not easy to get in this time, so trying to review the paper based on previous work. This paper is all about the basic knowledge of bio mechanics and useful to interpret and realization of forces act on tibia and femur, and anatomy of knee joint (beneficial for non-biological background people). In this paper, trying to discuss Dynamic (Explicit) analysis Ansys software) of knee joint, at different Q angles and free landing of knee on ground.**

Index Terms:- knee joint, Biomechanics • and knee joint forces, macroscopic, "Q" angle, and Free fall and knee anatomy.

1. INTRODUCTION

Artificial Knee replacement success rate nowadays is about 90 to 92 percent it happened because of improvement of surgical technique, though we can prognosis any potential defect/weakness, ultimately leading to the failure of the concerned body part. So we could see the importance of bio mechanics in our life, whether it is related to machines or human being. Scientist "hetzes" said Bio mechanics is the study of the movement of living things. Bio mechanics is a combination of biology and mechanics. In this paper, we are going to discuss Knee so in that term bio mechanics of Knee is nothing but study and analysis of knee joint, bones, ligaments and muscles. Knee joint Knee is "Hinge joint" made of two bones Thigh bone and shin bone. It was challenging to study the anatomy of Knee because who belong to non-biological background very help-full for them, so decided to write full anatomy and problem-solving process in only on paper.

1.1 A Basic Mechanism of the Knee

Femur (Upper bone of the leg) is forms a socket and ball joint with the pelvic arch, being held in place by a ligament within the socket, and by strong surrounding ligaments. In humans, the neck of the femur connects the shaft and head at a '125' Degree angle, which is efficient for walking. Tibia (Shin bone), located in the lower front portion of the leg. And this bone is second largest bone in the body. These two bones connect the ankle to the knee, and these two bones work together to stabilize the ankle and provide support to the muscles of the lower leg, however, the tibia carries a significant portion of the body weight.

Patella (Knee cap) also known as knee cap, is a flat, circular or triangular bone, which is connected with the femur and protects the anterior surface of the knee joint. Knee joint is the largest joint of human body, the function of knee joint is to

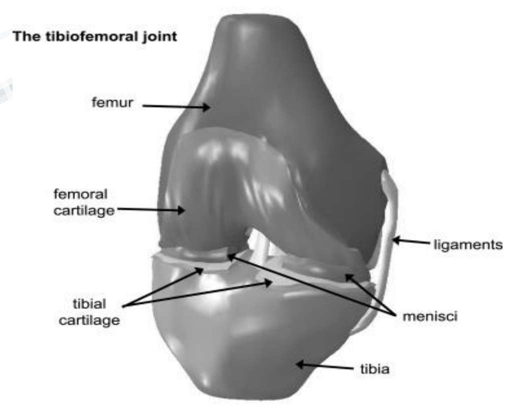

Figure 1. Anatomy of knee

Allow movement of the leg, and is critical to normal walking. Inside the knee a smooth articular cartilage that covers the joint surface, resting on the top of tibial cartilage is meniscus which improves the stability of joint and helps to distribute weight. Ligaments are important for controlling excessive motion, by limiting joint mobility especially side to side movement. Together these tendons and ligaments provide extension and flexion as well as medial and lateral rotation of knee joint. The quadriceps muscles play a very important role in the stability of the knee, and it joint on the top of the patella. Knee is made of three bones, the femur, patella and tibia. Here we are taking right knee of human and looking straight at it.

1.2 Knee joint and "Q" angle

Femur is also known as thigh bone. Tibia is a shin bone Patella is a Knee cap, Knee is complex joint with many different combination of parts: Tendon Ligaments Bones Muscles Movement of the bones cause friction in the articulating surface, to reduce this friction between all articulating surfaces involving in movement, are covered with a quite shiny and slippery layer called Cartilage. Articulating surface of femoral condyle and Tibia Plateaus cartilage and the back of the petal cartilage are covered with the Cartilage. This provide smooth surface that facilitate easy movement and further reduce friction.

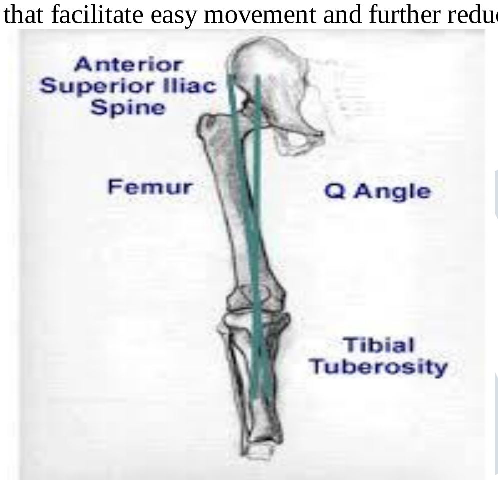

Figure 2. Q angle

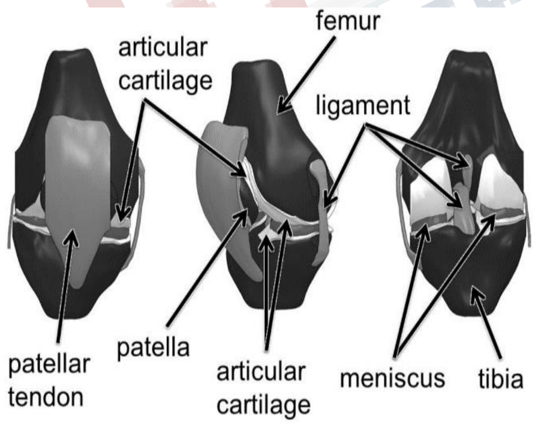

Figure 3. Soft Tissues of the Knee

Between articulating surface of the bones or "knee joints". Q angle in our knee must be able to support the weight of body during walking and running. Q angle is angle between quadriceps tendons and patella tendons. If we increase Q angle it will leads to fracture of Patella. Take Patella periphery and patella center and tibia draw a line from center of Patella and the second is from tibia to periphery of patella to measure "Q" angle. Software. My analysis is based on software for the analysis of knee flexion, firstly we have to build a 3D model which include tibia femur and soft tissues of knee. It is very difficult to analysis of soft tissues of knee so my word is limited to dynamic analysis of femur and tibia.

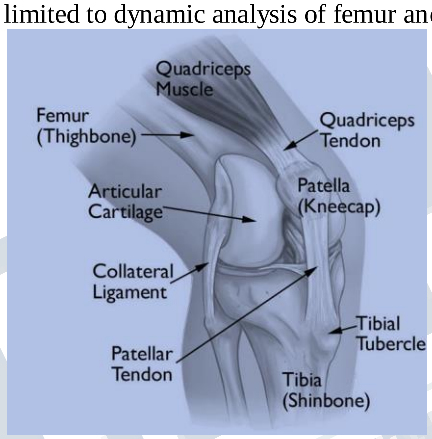

Figure 4. Knee bones

Role of knee joint in human gaiting system

It is important to set of method of bio mechanical feature of knee joint motion and stress during high flexion which we can feel in daily life. It is very difficult to analyze knee joint stress and motion, but there are some effective analysis method through we could easily analyze them. Some method done in laboratory and some based on software. My analysis is based on software for the analysis of knee flexion, firstly we have to build a 3D model which include tibia femur and soft tissues of knee. It is very difficult to analysis of soft tissues of knee so my word is limited to dynamic analysis of femur and tibia.

Materials and Method

Material, Methods of creating 3D model, and Research Motivation. Nowadays, several methods to build 3d model of the knee, because of highly requirement of precision results. some specific software including "Mimics", X-ray image to construct 3D model, laser scan technique, Image processing, slicer reverse engineering and rapid prototype. Mainly focused on "Mimics" software, so some necessary information about mimics' software ia, "Mimics" is a Materialize interactive medical image control system or software

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which used to build 3D Model of complex shapes, and also used in 3d printing. For the construction of the 3D model of knee, we need an MRI and CT scan of the knee of a healthy human. Moreover, by importing that images in mimics' software using thresholding and segmentation, we can quickly develop a 3D model of the knee. Research Motivation Bio-mechanics is the Part of mechanical engineering and principles of living things. It deals with organisms at a different level. A combination of engineering fields deals with different levels of complexity, which is not possible by only the biomedical field, like analyzing the forces before actual practice is the basic need of engineering in the medical field. The bone modeling cycle at bone mechanics is very challenging for everyone who's belonging to this field in mechanics and bio mechanics, continuously changing structure and micro structures is provided basic changes in the bone mechanical properties. Small strains behavior in tissue, the bone scan shows large changing shape, this changing shape because of applying external forces remodeling. Everything there makes bone a very good living tissue model of the prototype for the applications of the methods of Finite Element Analysis or in continuum mechanics. This modeling process is open systems mechanics to deals with the bio mechanics system. This may be responsible for bone growth and analysis across the scales.

Table 1. Properties of Materials

Materials	Youngs modulus In (MPa)	Poissons ratio in (MPa)
Bone	17400	0.3
Ligament	60	0.3
Cartilage	12	0.45
Meniscus	59	0.49

2.1. Paper Title

Dynamic (Explicit) analysis (FEA) of the knee joint during Knee flexion movement.

2.2. Authorship

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Email I'd is richa01.rai@gmail.com.
Designation-Student, and Department is Mechanical Engineering Department.

2.3 .Literature Review

Author Blankevoort in 1988, Kempton in 1980, Mow in 1982, and Walker 1972 Roth 1977 were worked in the very beginning and their title was to find how we do FEA on knee joint. Their research work based on Effects of articular contact 3D show the mathematical model of knee Joint, find the value of joint kinematics, at two different positions ,and result is Indirect motion of knee joint and their motion characteristics was simulated. Contact study of knee this can shows that FEA can do 2D and 3D analysis.

In 1991 Author Blankevoort and walker develop articular contact 1991, title of their research was Effects of articular contact 3D mathematical model of knee Joint, their research mainly based on find the value of joint kinematics, at two different positions. And the Result is ligaments and articular cartilage's mechanical property were found. Author Mr.Vaziri in 2008 constructed the first 2D model of the knee. Their title of research was The asymmetric 2D model was constructed,

Vziri research work was mainly based on studies and analysis of contact position of knee joint, result is knee kinematics and non-linearity of the model, Author Herzog and Donzelli in 1999, Mr. Un and Wilson in 2001 and 2005, Dar, Aspen and Wilson in 2003, Vadher and team in 2006, Modified form of Vaziri et al. 2008 model. title of their work was The geometry of 2D model taken and research work was mainly based on axissymmetric and lot equivalent to the 3D model. And the result is Provide necessary information about the knee.

Author Trent and team in 1976. Bartle, Zuppinger and Wang in 1973 1904, Markos in 1976, Walker and Hsies 1976; Wang and Walker 1974. Title of work was An analytical model of 3Dimensional knee (Tibia and femur) with the articulated surface of the knee. Research work mainly based on Ligaments study was performed for the first time. And result was the rotation was the knee, isometric behaviour of knee joint and, the extension and flexion of muscles were performed. The articulating surfaces face and femur, tibia, and patella were studied. Author Penrose and team in 2002, Blecha in 2005, Author Halonen and team in 2013, Zheng and Yang in 2014 and 2010. Author Wang and Kiapour in 2014, Author Miyoshi and team in 2002. Author Gardiner and Weiss in 2003,Author Guess in 2010, Author Li in 1999a, Author and team in 2008, Author Mootanah and team in 2014, Yao and song in 2006b and 2004,Author Son Monomer in 2012 Pe˜na et al 2007and 2008. Their work title was 3D model of human knee (with soft and hard tissues) by using MRI and CT scan. Research work of their work was, 3 Dimensional of the knee first developed and was a very big achievement in the bio mechanical field, Finite element of the knee which includes tibia and femur and predict or analyze knee forces and knee kinematics while a load is applied (external). And result based on Ligament and articular data were taken from "Blankevoort et al." and analyzed mechanical behaviour of knee.

Author Li and team in 2001a, 2002 and 2005, and their work title was 3D model of the human knee (with soft and hard tissues) by using MRI and CT scan. their research work was Modify the above work Study of Author Li of the knee is provide a contact of articulate surface, and Result articulate surface and experiment of damage of ligament and articular surface when the load is applied.

Author Mr Jolivet in 2001 and Li et al 2009, Limbert and Little et al. in 2004 and 1986, Meakin2003, Pandy1997, Penrose2002, DeFrate and his team in 2004, Donahue and Donzelli in 1999, Author Hirokawa and Tsuruno in 2000,

Author Izaham in 2012, Author Mr. Johansson and team in 2000 after reviewing their paper decided to work on biomechanics, Morimoto in 2009, Zhang and Zheng 2014, Zhu in 2015, Harris et al. 2012. Title name Modelling of the 3D knee joint, Research work was They all are worked and modify the knee model and make it modern any many ways. And the result For finite element analysis, these models are extensively used in current FEA analysis.

Author Wang, Kun Tao, Li, and Chengtao Wang in 2014. Work Title was Modelling and Analysis on Biomechanical Dynamic, Characteristics of Knee Flexion Movement. Research work based on 3D model of the knee was build including tibia, femur and soft tissues ok knee. And FEA analysis was done At 30 degree of knee flexion. and Result is Patellofemoral contact joint unsteady, 30 to 90 degree it Title Suppressed Due to Excessive Length 7 will drift from its original position. At 0 to 90-degree stress 9MPa was applied and simulate, contact above 90 degrees at 130 degrees it will reach to 22MPa. Bhaskar Kumar MADETI, Srinivasa Rao2014 Biomechanics of knee how knee works and in the field of biomechanics. Static and dynamic analysis of knee joint. Author Shinya Miyoshi 2002 Title of their work By using a 3D model of knee, analysis of the shape of the tibial tray by using FEA. Research work was to evaluate stress and displacement of using FEA. Result was to find out von misses stress and displacement, there is no difference in their values. Brandi C, 2009 model and bio mechanics review Basic idea of knee implant In case of aseptic loosening, very difficult to do surgery for the second time, it may fail the implant of the knee.

Author Kunyang Wang,Soroosh Haji Hosseinnejad, Ali Jabran, Bill Baltzopoulos, Lei Ren, Zhihui Qian. Title of their work 3Dimensional stress and stain bio mechanics analysis on the patellar tendon during knee flexion During 0 degrees to 90 degrees knee flexion may be fast and slow and slow walking. Research work was, The effect of this on the patellar tendon. and the result based on Stress and strain are maximum at zero to 90-degree knee flexion.

Literature review based on FEA analysis.

[31] 3 Dimensional cases to be analyzed "Eight" cases studied, number of elements and nodes is 456,302 nodes, and 258022, types of elements "Tetrahedral" and the boundary conditions type element mesh Frictionless contact type, and the bottom edge is restricted, and mechanical property is considered linear

[1] 3 Dimensional, cases to be analyzed "Four" cases studied, types of nodes and elements 12388 elements of tibial meshed part and 2238 nodes. meshing type "Triangle" , and the boundary conditions was type of element mesh Frictionless contact between tibia and femur, tibia bottom edge eight nodes full restricted. Separate and reduce top model.

[2] 2 Dimensional cases to be analyzed "Eight", number of elements and nodes "Four" femur contents and "two" direct contact condition. 3116 Nodes and 4615 elements, types of elements "Tetrahedral" type of elements mesh Left edge of . and the boundary conditions is the femur is fixed to create static symmetry, the bottom surface of tibia restricted to avoid motion.

[22] 2-dimensional bones and ligaments but soft tissues is 3 Dimensional, number of case to be analyzed "one" only one case has been studied 25000 elements have been taken Types of the element is "Solid" Surfaces value for boundary condition is found from the 3D amount of vivo, to find kinematics of 3D knee is fixed at ground.

[23] 3Dimensional "Four" cases analyzed, 8906 Nodes and 8923 elements Element of Tibia surface is "Hexahedral" Tibial surface fixed at the base, and bone base posterior also fixed.

[24] Explicit Dynamic FEA analysis of knee "Nine" cases analyzed, in which "one" point is coarse mesh with step size is 0.5, and the second is also have "one" case for fine mesh having step size 0.04. Mesh has three friction level for fine mesh, l is equal to 0.01, 0.04, 0.07. A total number of fine mesh has 7278 elements, and

2019 is the number of coarse mesh elements. Types of a node is "Hexahedral", and the total number is "eight". For rigid body components and tibia, there is "four" nodes Force axially applied, torque internally and externally applied. The angle of extension and flexion applied during gait. Femur force exterior or interior used and provide an only translation. Rotation 8 Richa Rai. of Femur has been taken as internally or externally at 0.30 N m/deg, and displacement of the knee when the load is 10.4 N/mm applied.

[25] 3Dimensional, Explicit dynamic analysis of knee, and 3D is a femoral component."Six" cases have been analyzed; a new part is frequencies which is "two" one is at 0.5 and other at 90.1. Tibial component or element is 29447; Patellar features is 20444. Fine and coarse meshing included, the nodes of the Patellar elements for fine mesh is 10136, and rough mesh element is 2239. "Eight' nodes which is "Hexahedral" in shape. It also has a "Triangular" Node which shows femur components. Tibia has both types of loads. First one is a translation of interior and posterior of the tibia, and second is the rotation of tibia internally and externally applied. Torque internally or externally has been applied, and femoral angle for rotation, flexion and extension is 0.30 N m/deg and displacement is 10.4 N/mm. A new part is frequencies which is "two" one is at 0.5 and other at 90.1 taken as boundary conditions.

[31] 3 Dimensional Tibial component. "Eight" Tibial component cases studied and analyzed. Not applicable number of elements, Not applicable for tibial component and rigid femoral components. Boundary conditions applied on Both the elements in flexion and extension 3000N and 1500N load applied.

[27] 3Dimensional analysis "Three" cases analyzed Total 11232 meshing elements "Eight" nodes, the solid component of Tibia is taken as a rigid element. The tibial component base is fixed and in femur boundary condition vertically part set.

[29] 3 Dimensional analysis Total "Six" cases I have analyzed. Contact analysis between tibia and femur under 3200N load and 45-degree flexion, 2200N load and 15 degree and 2800N load at 60 degrees. And for Fatigue analysis, there is three loading conditions 4000N, 2000N and 500N, Total number of meshing elements is 256705 for contact analysis. And for fatigue analysis number for meshing elements is 109643 "Four" element nodes. "Tetrahedral" element type is used for Tibia and femur. Ten nodes are used to analyze tibia. Boundary condition is Contact analysis could be done by fixing the tibial base. Fatigue test can be done by specifying half of the tibial base, and free another half.

[28] 2 Dimensional analysis Total "Four" cases analyzed and this paper based on femur components of the knee joint. A total number of an element is 1280, and 560 node value is used. Direct strain condition is used, and it will be applied at the center of straight strain. Boundary conditions, the Femur center component is fixed and constrained in both vertical and horizontal direction.

[26] 2 Dimensional analysis for direct material property and 3 Dimensional analysis for Finite Element of the knee. "Two" cases were studied based on contact of knee bones, and "Eight" cased analyzed based on loading condition. Total 560 nodes and 1280 element were used during meshing of the knee for FEA "Eight" nodes is used for translation in plane strain condition. And "Four" node element is used for rigid FEA analysis of knee.in boundary conditions Only Tibial element allowed FEA analysis of knee and give freedom of movement.

2.4. Knee geometry

Complicated to model without having any flaws because, flaws in construction could exploit our calculation, so we will use MRI data to create a 3D model of the knee in MIMICS or SLICER. MRI is magnetic resonance imaging; firstly, we need MRI of a healthy volunteer (5.6 Feet, weight 60kg) and a DICOM image file of MRI.

The 3D model depends heavily on images and what we want our final images to look like and how the model used. We start from segmenting (is a process to increase the resolution of images) DICOM images export is the software and choose threshold menu, and after thresholding click on 3d preview, we will get mask segmentation.

Now 3D model of the knee which has soft tissues and bones.

Procedure Materials for the Analysis of knee, it is very important to know about mechanical properties of bones, property of bones depend on gender, age and in which environment we are living.

Here is table which shows the material property of knee which we are going to use in our analysis. Knee which we are going to use in our analysis. Many references have taken of the Author Jacob and Hull Rashid journal that a healthy man weight is 30 years, 5feet 6 inch tall and weight is about 70kg , force of 1400N is applied, normally it would be double of weight this loading condition have been taken from Ayala and Morales. We have applied displacement approximately .010meter, all the data which we have been taken will be very useful to analyzing maximum and minimum deformation that soft tissues can swear without failure.

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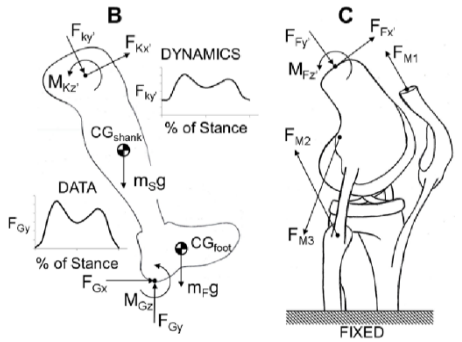

Figure 5. Knee Geometry

2.5. FEA Model

FEA is a finite element analysis based on the Finite element method, this method we used to predict the behavior of Heat flow, the behavior of solids, heat conduction of fluid flow, Euler's equation, Displacement

Table 2. Properties of Material and Loads

Kind of Material	Youngs modulus (MPa)	Poissons ratio (MPa)	Bulk modulus (MPa)	Shear modulus (MPa
Femurr	17,000	.3	14,167	6538.5
Tibia	14,000	.3	11,667	5384.6
Cartilage	5	.46	20.833	1.7123
Menisci	59	.49	983.33	19.799

Estimate is 10mm, Model This paper include a combination of tibia, femur, patella and menisci. The only external load will be applied. The complexity of the model of knee push to take 0-degree flexion of extension. Moreover, bones based on linear Analysis, and soft tissues include non- linearity: static Analysis and many more.

The finite Element Analysis tool is top-rated and effective nowadays in Engineering and non-Engineering field. FEA provides results with precision, real-life scenarios with accuracy, versatility, and practicality. FEA is working on finite element method. Which deals with practical problems. FEA used to calculate or solve approx. The solution to real-world problems.

It based on the Mathematical model of the Differential equation. FEA perform further Analysis and also it converts Mathematical differential equation into the set of linear equations. For Engineering problem Differential equation is playing a significant role because the language of physical laws is mathematics. Differential equations connect everything like changes in displacement, the geometry of objects, physical properties, temperature and pressure, and more. Very difficult to the Analysis of soft tissues so, to avoid kinematic Analysis of knee, all the component of the knee has taken rigidly. In many research, paper authors have described Finite element model of the knee, which includes bones and soft tissues of the knee like tendon, patella, menisci and bones. The ligament is hyper-elastic and isotropic, Bones have taken as a rigid body, but the cartilage is taken as linearly elastic, homogeneous and isotropic.

The model which I have explained was taken and validated by using experimental and software results.

Importing medical data in mimics software

In mimics software we can import 420 DICOM images of CT scan, so I have taken CT scan of 30 years old man left knee. FE model of knee has been created and meshing is also done through

MIMICS software very easily. Meshing is very important while analyzing the model and reducing analysis time, so meshed with triangular element or Hexahedron units adopted in bones and tissues to reduce calculation time.

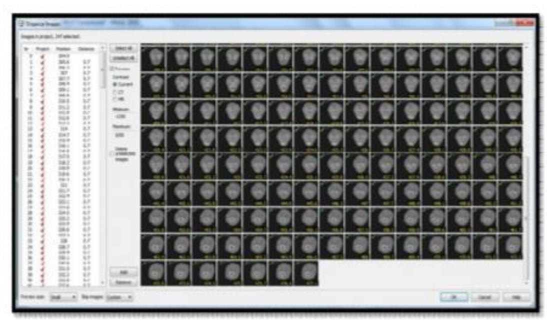

Figure 6. DICOM Images in mimics

Most important thing is how to import CT scan or MRI report images (DICOM format) to mimic software. Go to file, choose new project wizard and import my raw DICOM images or file of knee then hit next. Now we can see preview of our DICOM images, and all the in available. Select the study you want to import. Now it converted in mimics' project file, which will contain all our images file. We can change the orientation of our images.

In the below figure, 3 planer view of images given and these images is used to convert into 3 dimensional view of knee.

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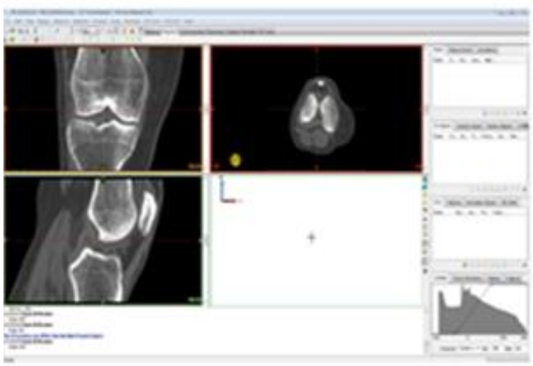

. **Figure 7.** Three planer View of Knee joint

We will get 3 planner view of my knee joint. Top left is coronal plane, top right is axial plane, bottom left is sagittal plane and in bottom right is 3D window in which any 3D model can be create. Right hand side of the software is project manager, which we have different tabs like segmentation etc. Right hand side bottom right we have contrast tab, which we can used to adjust the windowing of our images, by dragging point around. Hold and right click drag mouse left to right can change the brightness of your images, Drag mouse up and down to change contrast your window. Segmentation AND Thresholding Segmentation An MRI or CT scan Image is imported in MIMICS Software, This software converts the two-dimensional image into the three-dimensional solid geometry. Segmentation is begun by cropping and providing right or required image in three view names is sagittal, axial, and coronal. Mimics software reduces unwanted segmenting and fixed the wanted or required geometry. Profile line is in axial view in between two extremities of bones femur and tibia. Threshold operation is used to create mask. This mask connects all the region in same thresholds area. The mask which create automatically is green mask it shows after completing the threshold in cropping region. We use multi slicer editing between femur and tibia to create growing operation. Most commonly used tool to create initial segmentation object. Go to the segment menu.

So "Thresholding" is the process of choosing the range and intensity values that used in any of the pixels that will fall within a range get highlighted or selected and put into our segmentation. Number of pixel on Y axis and value.

Go to file, choose new project wizard and import my raw DICOM images or file of knee then hit next.

Now we can see preview of our DICOM images, and all the in available. Select the study you want to import.

Now it converted in mimics' project file, which will contain all our images file. We can change the orientation of our images. We will get 3 planner view of my knee joint. Top left is coronal plane, top right is axial plane, bottom left is sagittal plane and in bottom right is 3D window in which any 3D model can be create. Right hand side of the software is project manager,

which we have different tabs like segmentation etc. Right hand side bottom right we have contrast tab, which we can used to adjust the windowing of our images, by dragging point around.

HOLD AND RIGHT CLICK drag mouse left to right can change the brightness of your images, Drag mouse up and down to change contrast your window.

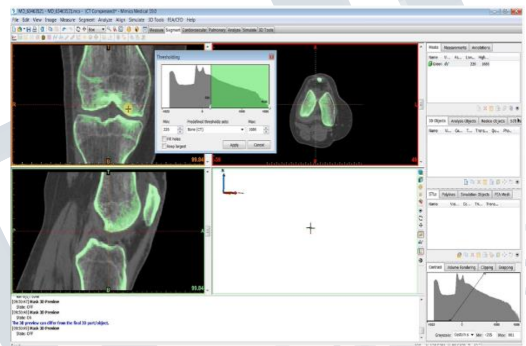

Figure 8. Thresholding

of image are along the x axis. We can choose or change our range by dragging the sliders or mouse left and right, and one is minimum value range and one is maximum value range. So we can see as we drag the mouse the pixel will

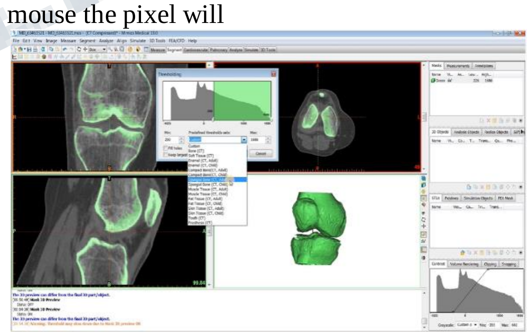

Figure 9. Segmentation

Update in real time as well as my 3d view. It has some predefined sets of CT scan. Coefficient of friction has been taken .038 to articular surface. Calculation of knee joint is easy and flawless when we formulate knee joint torque, force and internal joint. So we can see as we drag the mouse the pixel will update in real time as well as my 3d view. It has some predefined sets of CT scan. Coefficient of friction has been taken .038 to articular surface. Calculation of knee joint is easy and flawless

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when we formulate knee joint torque, force and internal joint.

2.6. Dynamic Analysis at"Q" angle

Loading and boundary conditions. Meshing had been performed in Mimics software, Meshed 3 dimensional model of knee joint imported into the ANSYS Software. This Finite Element model has 258222 elements and 456300 nodes. Femur, Tibia and Patellar mesh density input is 2mm.Mesh refinement is very important part of any Finite element Analysis, which provide accurate and error free result. But very refined meshing would take so much of time, that's why we refined

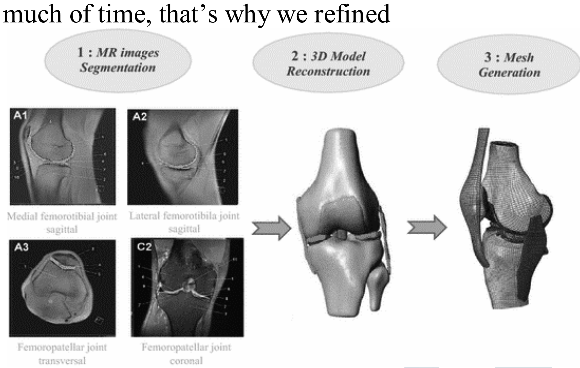

Figure 9. MRI to 3D Meshing

The mesh where we need accurate result. Angular distortion of any shell element reaches to zero, this phenomenon is called SKEW. This skew tell us about mesh grade. So try to keep it as minimum as possible. The value of orthogonal quality (taken from Emrah and farukh) is greater than 0.1 and maximum is less than 0.95, average value of skew taken as 0.46 and average orthogonal value is 0.69 and according to the mesh refinement this is quite good result. Loading imposed 350 N on Femur in axial direction, and other 56 N is on the Tendons, so there are two important loading as explained above. The Femur load is applied axially and Tendon load applied upward direction. Here we fixed the surface of Femur and Tibia, for easy calculation we are taking friction less contact between femur and tibia. According to Finite Element Analysis we will talk about Von misses.

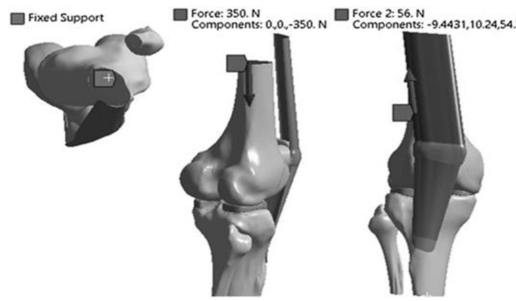

Figure 10. Loading Conditions

Stress. The main focus on the daily gaiting system of human based on Q angle. Q angle has been taken 10 degree, 15 degree and 22 degree. The most effected part by above loading condition is at 22 degree, at which Tibia, femur and patella have most deformation compare with 10 Degree and 15 degree angle.

Results Here is the result which describe the stresses at different "Q" angle and at different loading condition. At angle 22 degree stresses in Femur, Tibia and Patella is 14.6 MPa, 9.2 MPa and 2.2 MPa. At 15 Degree angle stresses are in Femur, Tibia and Patella is 4.3 MPa, 4.9 MPa and 1.2 MPa, same goes to 10 degree angle stresses are 12.5 MPa, 8.4 MPa and 3.8 MPa. Below in given table I have describe the material (Femur, Tibia, cartilage and menisci) properties. And in second table.

Table 2. Stress Conditions

Materials	Young modulus (MPa)	Poisson ratio (MPa)	Bulk modulus (MPa)	Shear moduluss (MPa
Femurr	17,000	.3	14,167	6538.5
Tibia	14,000	.3	11,667	5384.6
Cartilage	5	.46	20.833	1.7123
Menisci	59	.49	983.33	19.799

Table 3. Stresses at different Q angle

"Q" Angle	Tibia cartilage (MPa)	Femur cartilag (MPa)	Patella cartilage (MPa)
15	4.2	4.6	1.1
10	12.6	8.7	3.4
22	14.5	9.1	2.4

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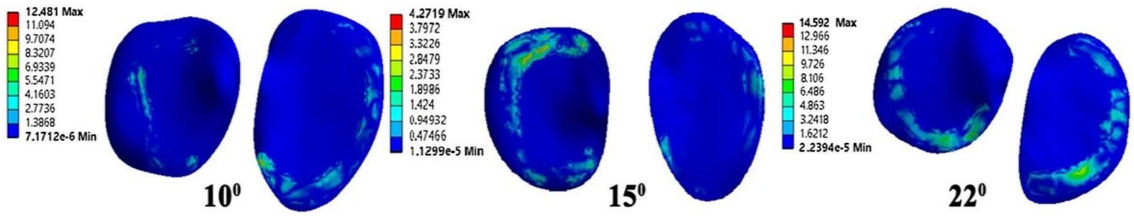

Figure 11. Stresses in Tibia

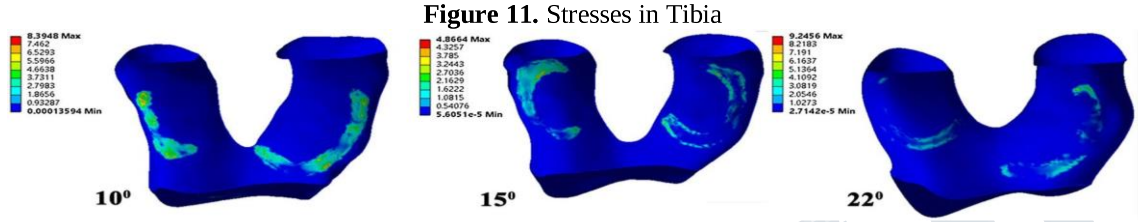

Figure 12. Stresses in Femur

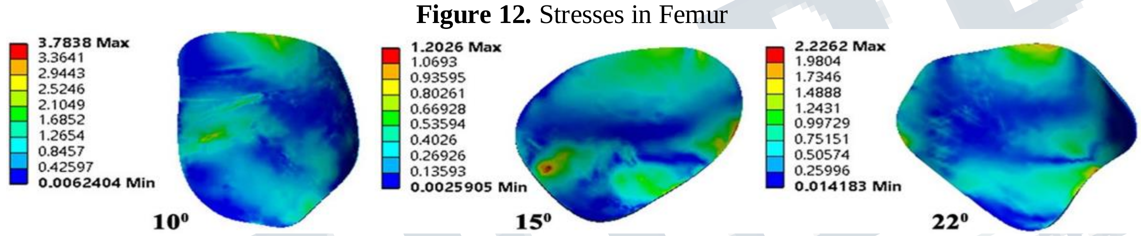

Figure 13. Stresses in Patella

From above diagram the value of stresses at different “Q” angle, could see the major deformation. Stresses in Femoral cartilage Stresses in Femoral cartilage at Different Q angle is, at 22 degree, the value of stress is 9.24MPa, the value of stresses at 15 degree is 4.86 MPa and value os stress at 10 degree is 8.39 MPa. From above result we could see the major deformation is find in Femoral cartilage ia, at 22 degree at given loading conditions. Stresses in Patellar Cartilage Stresses in Patellar cartilage at Different Q angle is, at 22 degree, The value of stress is 2.226MPa, the value of stresses at 15 degree is 1.206 MPa and value os stress at 10 degree is 3.78 MPa. From above result we could see the major deformation is find in Patellar cartilage is, at 22 degree at given loading conditions. So we can see the above discussion and classified that, in above three discussion the Patellar cartilage at 15 degree Q angle will be lower middle region at which we could see lowest stress in all Q angle and also when we comparing with others**.**

2.7. Analysis When Knee Free Fall On Ground

Procedure Displacement will be taken as 10mm, Tibia Meshing is done and tibia have total 12288 elements, lower part of tibia restricted which is zero in all direction. 1400 N load has been applied on it and distributed all over the tibia. Femur Meshing of femur was done by using ansys software, total 21263 elements and 1400N load applied, femur simply supported and this load imposed all nodes of femur. Out of 10 nodes 8 nodes restricted, UX is equal to zero and UZ also zero to avoid translation. Menisci Total meshed element is 2734 and it is simply supported in lower part. 1400 N load applied and load distributed all over the nodes of menisci. X, Y direction is free but Z direction is restricted equal to zero. It shows, anterior and

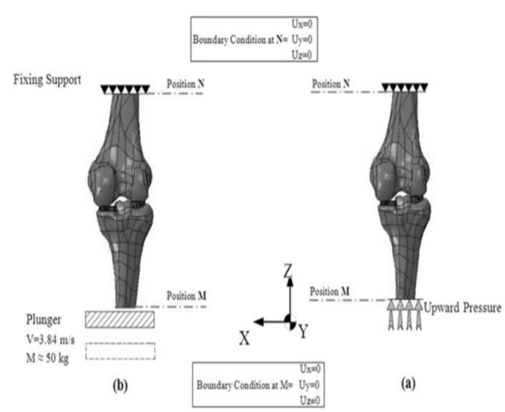

Figure 14 . Boundary conditions for free fall

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Posterior views of knee joint in Mimics. The 3D models were exported to 3D matic software. In 3D-matic, the number of triangles is reduced and the aspect ratio of is improved so it shows suitability of the mesh for finite element analysis. The mesh is generated by using Solid elements method in Ansys software. SOLID element is a best resolution 3-D element, it has 10 nodes, and every node has 3 translation direction x, y and z and quadratic displacement behavior. It is suitable for regular and irregular modelling meshes. The meshed models are exported to ANSYS Workbench. The number of nodes and elements used for the model is 116,616 and 52,951. The menisci, cartilage, ligaments and bones are assumed to be isotropic and linearly elastic.

We will take same material properties as above. The contact between femur and tibia is represent the contact between

Table 4. Different Stresse Conditions and Property of M

Materials What we used	Young modulus in MPa	Poisson ratio in MPa	Bulk moduluss in MPa	TheShear modulus in MPa
Femurr	17,000	.3	14,167	6538.5
Tibia	14,000	.3	11,667	5384.6
Cartilage	5	.46	20.833	1.7123
Menisci	59	.49	983.33	19.799

Cartilage and bone, ligament and bone, and the medial collateral ligament to the medial meniscus. Separation contact we cannot defined between the tibial cartilage and femoral cartilages, in between cartilages and menisci and the patellar cartilage and femoral cartilage.

Flexion-extension are constrained for the femur to analyze the knee joint extension. The fibula and tibia are constrained at the lower surfaces. A compressive (vertical) force of 1400 N applied to the top surface of the femur, it matches with the force of the full extension position. The finite element and knee joint model with boundary conditions we can see below. FEA of the joint (knee) performed with the discussed boundary conditions (BC). The full model Contact stresses were calculated but my main focus is on the femur, menisci and tibial cartilage which is necessary.

During free landing applied load on the feet varies. This load varies according to the ground condition, Height from the ground, landing direction, and position. These Three different landing positions shown below. Height increases the magnitude of load also increases.

Taking there is a significant difference between impact and falling from a height. Time for analysis is .04 sec have been taken. and the total time to land is 20 sec. Landing time may be added to 5 sec. Height of 75cm estimated when subject velocity is free fall. The main focus is based on analysis of stresses like, the Von-Misses Stress (VMS) and maximum and minimum Principal Stress. The maximum compressive

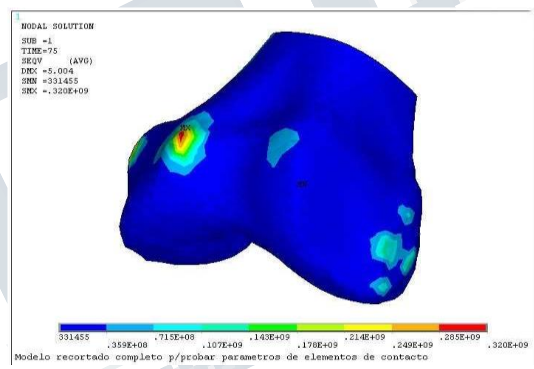

Figure 15. Femur Stresses

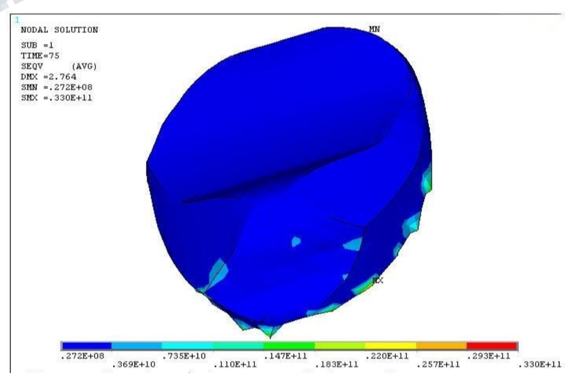

Figure 17. Patella Stresses

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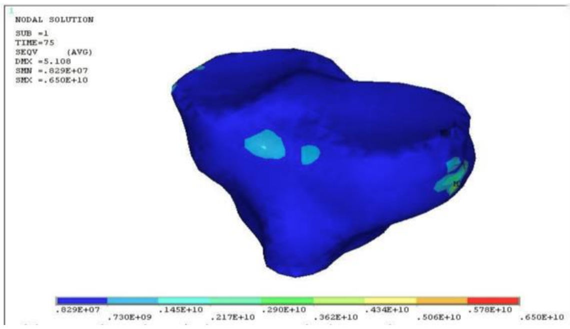

Figure 16. Tibia stresses

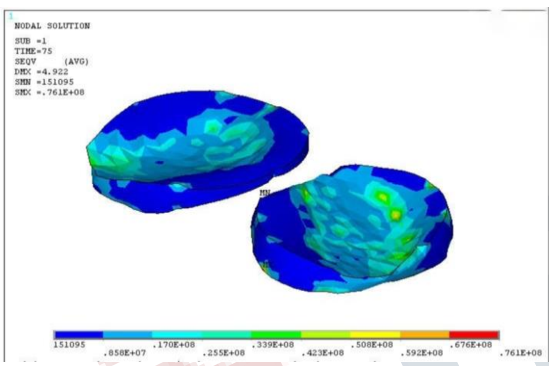

Figure 18. Menisci stresses

Stress of 3.3MPa and the maximum VMS of 2.91MPa are located on the back portion of the femoral cartilage.
The magnitudes of principal stress of 3.3MPa and VMS of 5.2MPa maximum on the medial meniscus as compared to the lateral meniscus with 2.91MPa and 2.0MPa.At lateral femoral cartilage compressive stress is -13.3MPa which is greater than the medial cartilage which is -6.6Mpa.Tibial cartilage depicted compressive stress, Knee joint Cartilage provide impact force in upward direction. That is the reason these Components absorbed greater impact. On medial Cartilage peak nodal value is modulus value of the meniscus is approximately 11 times more than cartilage value. Cartilage deformation is more. Medial meniscus contact area is greater, and about 55.66 and 8.97MPa.

2.8. Results and Discussion

In the above analysis, there is two analysis which could give a roughly idea about, the impact of Q angle in our knee joint and knee free fall on ground with the same loading condition. To avoid misalignment of knee joint Q angle playing important role so Analysis on Q angle should be taken. In my discussion exact value not determined due to excessive stress on cartilage. Pressure below 4.5 MPa is main reason to cell death of cartilage. In experimental analysis and observed that high pressure can change in tissues of cartilage. Distribution of stress depend on loads what we applied, geometry condition and boundary conditions. Well-functioning knee is very important for mobility, Knee must be able to support body weight during walking and running. Normal alignment of knee is important for knee function. Q angle provide useful operation and give important function and alignment of knee joint.an increasing Q angle is risk factor for patellar subsection. In knee flexion the normal Q angle is 14 degrees for male and 17 degrees for female. Q angle inflexion is approximately 8 degrees. For females an increased Q angle linked to knee pain, ACL (Anterior cruciate ligaments) Injury and patellofemural pain. The alignment of patellofemural joint is affected by the patellar tendon lenght and Q angle, after Q angle extension is first one is External tibial torsion, second is Femural anteversion and many stresses. CT scan study found to be very helpful in Q angle analysis.
Impact of knee when free fall on ground and flexion and extension, Quadriceps muscles play very important role and it anchored on the top of patella. Patellar tendon act in downward direction. Constructed in a 3 Dimensional model of the knee joint was in the mimics' software and analyzed with the FEA. An axial compressive force applied on the joint. My main objective is to find out the contact stresses by using finite element analysis (FEA). Many research paper whatever I read, they have used FEA to analysis of the compressive stresses in knee joint. The menisci of knee varied between 0.98 MPa in compressive stress in the externally is 3.96 MPa and the internally, under a compressive force of 1300 N. Author Dong. Found a compressive stress on both the lateral and medial meniscus is 3.00 and 2.83 MPa. Pena et al. were found that the compressive stress on the medial meniscus was 3.31 MPa. The compressive stresses on the lateral and medial meniscus was found on 3.5 MPa and 2.1 MPa. The difference in the value of stress, due to that frictionless nonlinear contact between the tibial and femoral cartilage, menisci and cartilage between the patellar and femoral cartilage is not considered. Normal active extension free fall is of the legs depends upon both quadriceps and patellar tendon. When we gain weight and not doing proper physical work, it increase chances of deformation, it may be von misses stress, shear stress and slipping of knee cap, and we unable to extend the knee. The same result with free landing of human gaiting system. Knee joint Cartilage provide impact force in upward direction. That is the reason

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these components absorbed greater impact. On medial Cartilage peak nodal value is modulus value of the menisci is approximately 11 times that cartilage value. Cartilage deformation is more. Medial meniscus contact area is greater, and about 55.66 and 8.97MPa.

Table 4. Results at Different plane

	Femur MPa	Tibia MPa	Patella MPa	Menisci MPa
Avg value	261.237	607.005	100.215	11.1417
X Direction	3.3377	4.9664	1.2575	.0158547
Y Direction	3.4754	7.40566	3.1142	.0681978
Z Direction	2.7584	17.7663	7.403	.00249752

3. Conclusion

A 3D model of the healthy volunteer knee built in mimic software, it has bones and soft tissues both like Cartilages, tendons, ligaments, menisci and bones. And analyzed under compressive force. The force of full flexion position. The analysis of final model compared with the literature results which is fully established, Title Suppressed Due to Excessive Length 19 which was true and based on actual and room based practical, observed that the contact between the tibial cartilage and femoral cartilages was built. The high load bearing and low load-bearing area were situated on the anterior and posterior part of the femoral cartilage. This analysis shows that medial meniscus is to rupture as stresses in the medial menisci are more as compare to lateral one. Modelling of 3 dimensional human knee joint in mimics' software is very useful for kinematic and dynamic analysis of knee joint on FEA or finite element analysis. To avoid complexity in the Analysis, all the assumptions taken from previous research work, Present work is thoroughly based on analysis of Knee joint including stresses and Friction. Explained each and everything about forces and Boundary conditions, which was main objective. Obtained results can be modified including reaction forces and stresses by analyzing it with other parameters.

Acknowledgements

This paper is based on previous research work, the higher concept is Doing Research. Research work test dedication, Patience and state of mind. Every result brings to arrive is a beginning for higher achievement. My project is a small drop in the ocean. I am very thankful to mentor "Prof Vikas Rastogi" his support and motivation provide me confidence to write and review the Paper.

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