VIBRATION ANALYSIS OF PROSTHETIC KNEES IMPLANT USING CATIA MODELLING AND FEM APPROACH

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ABSTRACT

In this research, vibration analysis of prosthetic knee implants is investigated that uses the finite element method. Arthritis seems to be the degenerative deterioration of the cartilage, which protects the tibia or femur at the ends of something like the Knee Joint. Because of the discomfort which creates within the knees joint, there is need of prosthetics parts to be installed right way. The prosthetic joints should not only be biocompatible but also adhere to certain design specifications. The implantation of these joints into the human body should not cause severe discomfort or need postoperative care.

Moreover, the durability and efficacy of such prosthetic joints will be of the highest importance. During the activation phase, the tibia and femur components come into contact, causing strains at the interface. These stresses, in turn, determine how well the joint functions comparing the acceleration experienced while walking and the most significant pressure difference that occurs during each stage of the gait (walking) cycle. This comparison is made using both stable and moving knee implants. This research aims to demonstrate the efficacy of static or dynamic alignment implants in various clinical scenarios and also to determine the relative cost-effectiveness of Knee discomfort throughout a lifespan. The objective of this research is to assess the tibial section depth and the effect of body weight on tibial bearing pressure. To analyze patients with an average weight and use with obese persons while also applying observations in ANSYS Workbench. This is done in combination with equal importance. Also aim is to analyze the effects of human frequency on various materials and shapes using ANSYS. For over four decades, finite element analysis has been used to study and evaluate essential mechanical characteristics of complete joint replacements. In designing, developing, and pre-clinically testing total joint replacements, the incorporation of finite elements is done.

Keywords: *Vibration analysis, Prosthetic Knees, Knee cap, Knee joint, ANSYS and FEM Approach*

INTRODUCTION

The geometric complexity and nonlinearity of the knee metals make it challenging to analyze the mechanical response of the kneecap. Two subfields of study exist within mechanics. Statics is the investigation of systems at equilibrium (with really no motion) or within constant motion with a velocity. Dynamical, the research of system in move with acceleration may incorporate both kinetics and kinematics. The study of the forces involved with motion, particularly forces generating motion & forces arising from motion, is known as kinematics. Kinematics is the analysis of bodies which move while taking time, movements, velocities, or velocity of movements along either a straight line or a rotating direction. This body component is one of the largest joints in the body, if not the largest, but it is also one of the most intricate. It can withstand significant strains & risks of damage in everyday life, the workplace, & sports. People who have anatomic deformities, including as knock-knees or along the every, may experience pain. Normal aging processes, obesity, and lack of physical exercise may cause joint wear and strain.

The knee joint in humans is a muscle mass rheumatic diaphoresis complexity structure. This knee consists of the quadriceps, tibia, fibula, & patella. In addition to bending and straightening, there is a tiny rotating component to the knee's movement. Throughout the knee joint, the quadriceps and hamstrings are the knee muscles. The quadriceps are located on the outside of the knees, while the hamstrings are located in the rear. Equally vital inside this knee joint are the ligaments, which keep it together. In summary, the skeletons supporting the joint and give the joint's solid structure, the two muscles the joints, or the ligaments stabilize it. Rheumatoid are a degeneration of the joints and the major source of impairment in those aged 55 and older. Atherosclerosis is the most prevalent kind of arthritis, which may be caused by joint trauma, joint infection, or age. Joint pain is the leading complaint of patients with arthritis. Neither rheumatoid nor osteoarthritis has a cure. Medications may help reduce joint inflammation, hence alleviating pain.

Methodology

The human body part is a complicated system of articulating bony frameworks that are subjected to high loads and large in comparison displacements during daily activities. Finite element concept studies have long been recognized but instead trusted as reliable complements to human articulation analyzation. The accurate control of packing, motion, boundary conditions, and formed on the basis in design parameters of joint response is one advantage of such numerical studies. Furthermore, the labral forces, contact forces/areas, and cartilage stresses are valuable model output results. In the investigation of TKR failure, numerical simulation methods have been widely used.

Problem statement of the study

For four decades, finite component has been used in mechanical total joint replacements. Complete joint substitutions will be employed in the creative, output, and pre-clinical research processes. To be appropriate, simulations must take a number of co approach that includes real-world considerations, be holistic and thus supported by data, and have a greater degree of corroborating evidence. ANSYS is the Girly examination of something like the joint when the knee is straight. With various combinations of analyses, biomaterial analysis can produce varying results. If the CATIA modelling is complete, the file will be shipped into ANYS and entwined into finite elements, or finite dampers, before the solid model is divided up into smaller units known as Content Property Dividing. Table shows mechanical properties of Titanium alloy and CoCr alloy which are available in ANSYS software.

Table 1 Material 1: CoCr: Cobalt Chromium

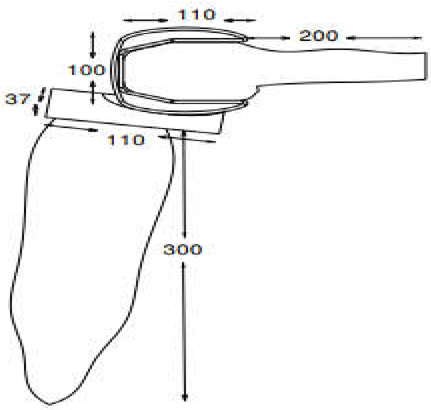
Sr no.	Properties	Value
1.	Density (kg/m^3)	7850
2.	Young's Modulus (Pa)	2x10^{11}
3.	Poisson's Ratio	0.29
4.	Tensile Ultimate Strength N/m^2	4.6x10^8
5.	Tensile Yield Strength N/m^2	2.5x10^8

Table 1 Material 2: Ti6Al4V: Titanium Alloy

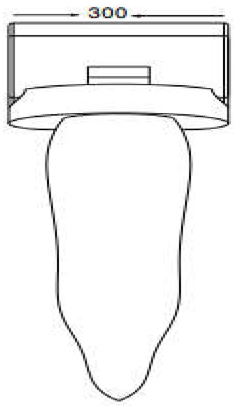
Sr no.	Properties	Value
1.	Density (g/cm^3)	4.506
2.	Young's Modulus (Pa)	9x10^3
3.	Poisson's Ratio	0.33
4.	Tensile Ultimate Strength N/m^2	4.6x10^8
5.	Tensile Yield Strength N/m^2	2.5x10^8

Four cases from the hospitals were taken for the analysis which included CoCr and Titanium alloy material

Case 1: 54-year-old

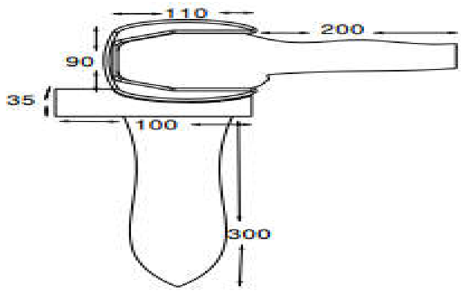


Case 1: 54-year-old

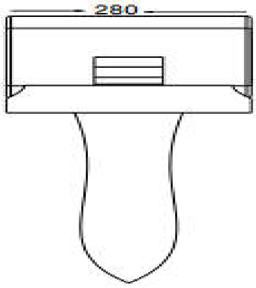


Case 1: 54-year-old: Side View

Case 2: 51-year-old

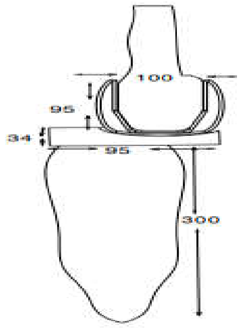


Case 2: 51-year-old

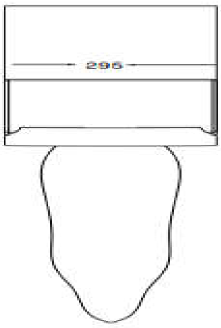


Case 1: 51-year-old: Side View

Case 3: 89-year-old

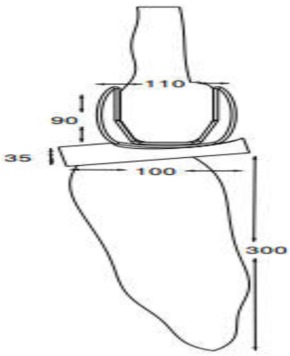


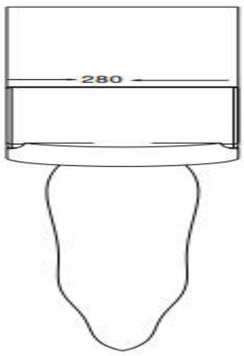
Case 3: 89-year-old



Case 3: 89-year-old: Side View

Case 4: 51-year-old





Material Properties of selected materials

Chromium (Made compulsory), titanium alloy (Ti6Al4V), and nickel titanium are the biomaterials under consideration for knees (NiTi).

1. **Material Properties of Cobalt-Chromium (CoCr)**

American Elements sells a variety of metal alloys under the brand name AE Alloys, including cobalt chromium. AE Alloys TM are readily available in most volumes as steel terms include bars, ingots, sashes, wire, shot, sheets, and foils. There are. American Elements satisfies all applicable standards for quality. Standards such as, standards. Both regular and customized packing options are available. Radiation shielding, bearing production, ballast, casting, and step circuit boards are some of the most common applications. The material properties in table 3.3 and 3.4 are available in Ansys.

Table 3 Material Properties of Cobalt-Chromium (CoCr)

Properties	**Values**
Compound Formula	CoCr
Molecular Weight	110.93
Density	10 g/cm^3
Electrical Resistivity	-6 10x Ω-m
Poisson's Ratio	0.29
Tensile Strength	1130 to 1900 MPa (Ultimate)/ 470 to 1600 MPa (Yield)
Thermal Conductivity	9.4 W/m-K
Thermal Expansion	12 µm/m-K
Young's Modulus	210 GPa

2. Material Properties of Titanium Alloy (Ti6Al4V)

A significant specific strength and outstanding resistance to corrosion. However, titanium alloys' poor ultimate stress and wear resistance have limited their biomedical applications.

Titanium alloys have a strong aerospace, transport, electricity production, and chemical sectors because to their particular strength, outstanding high temperature mechanical capabilities, and superior corrosion resistance.

Table 2 Material Properties of Titanium Alloy (Ti-6Al-4V)

Properties	**Values**
Compound Formula	Ti-6Al-4V
Density	4.429 Mg/cm^3
Resistivity	168 x 10^{-8} Ω-m
Poisson's Ratio	0.31
Tensile Strength	862 to 1200 MPa
Thermal Conductivity	7.1 W/m-K
Thermal Expansion	8.7 µm/m-K
Young's Modulus	110 GPa

3. Material Properties of NiTi

Ni-Ti alloy, commonly known as Nitinol, is an alloy of nickel and titanium in which the atomic percentages of nickel and titanium are almost equal. Ni-Ti is a shape-preserving alloy, meaning it can be bent or twisted at room temperature but then snap back into its original form when heated to high enough.

The alloy nickel-titanium Nitinol has recently been used in the production of endodontic instruments. Nitinol alloys are stronger than stainless steel alloys but have a slightly lower elastic modulus.

Table 3 Material Properties of Ni-Ti Alloy (NiTi)

Properties	Values
Compound Formula	NiTi
Density	6.45 g/cm^3
Resistivity	82×10−6 Ω- cm
Poisson's Ratio	0.33
Tensile Strength	1900 MPa
Thermal Conductivity	0.18 W/m-K
Thermal Expansion	11×10^{-6}/°C
Young's Modulus	75–83 GPa

CATIA

CATIA is a cross-software suite developed by French company Assault Systems for use in product lifecycle management, 3D modelling and visualization, CAD, CAM, CAE, and CAM. (PLM).

Here assembly of femoral component is done with the help of two supporting screws which act as articulating insert making it possible to move like ball and socket joint.

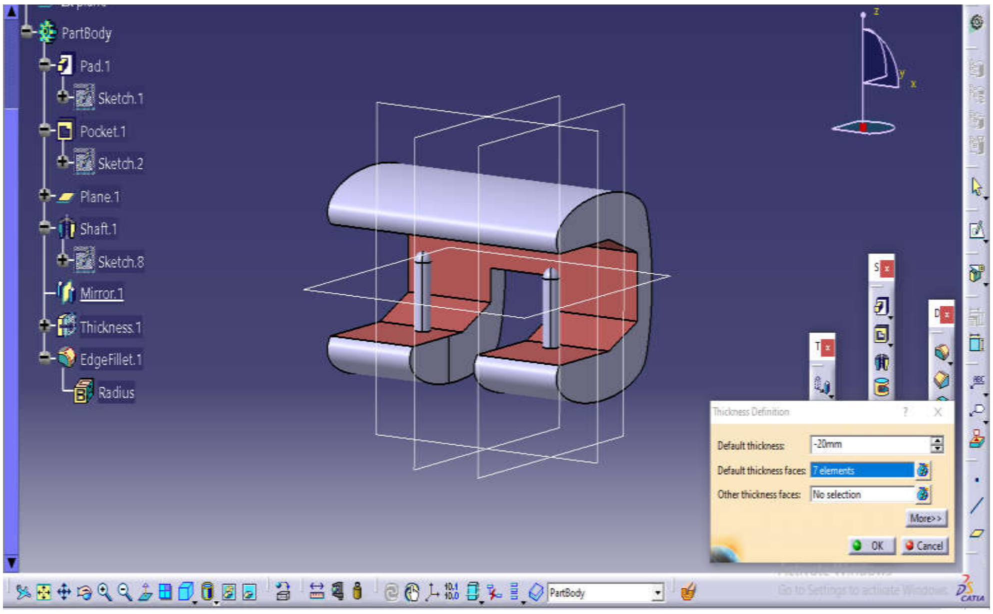


Fig 1 Femoral Component with Screws

Assembly of femoral component ready to assemble with lower tibia- fibula component.

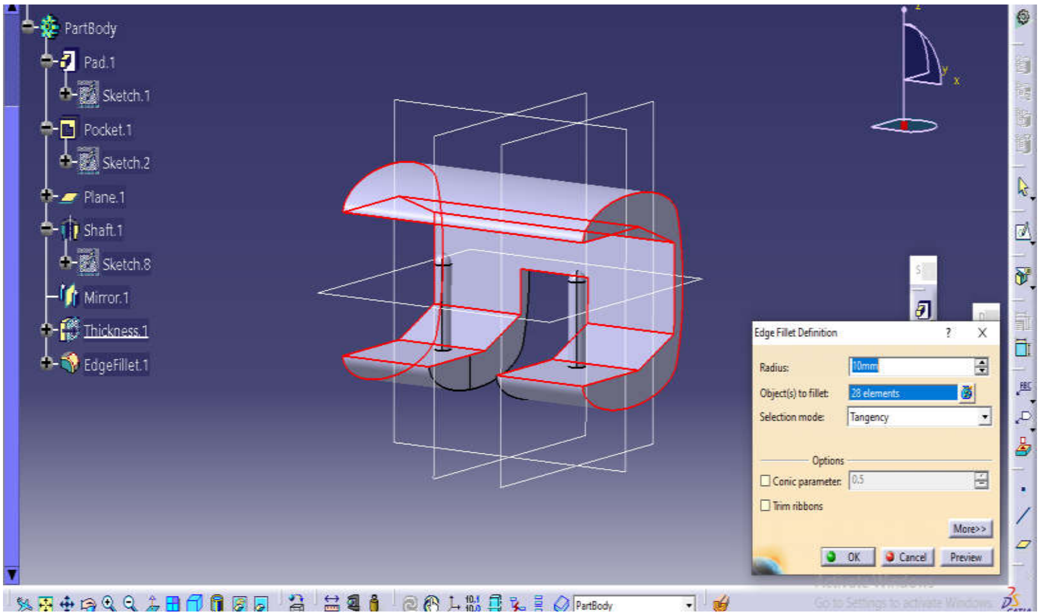


Fig 2 Assembly of femoral component

ASSEMBLY

Assembly of femoral component ready to assemble with lower tibia- fibula component.

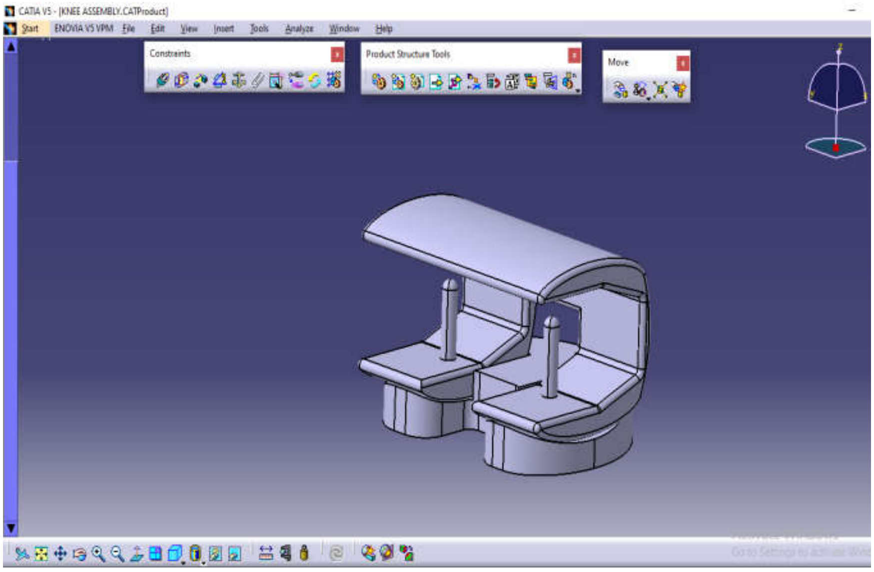


Fig 3 Final Assembly

ANSYS

ANSYS seems to be tool for numerically solving a wide variety of mechanical problems, based on a finite-element model. Examples of such obstacles include simulations, structural analysis, heat movement, fluid difficulties, acoustics, and electromagnetic issues.

Case Study Details

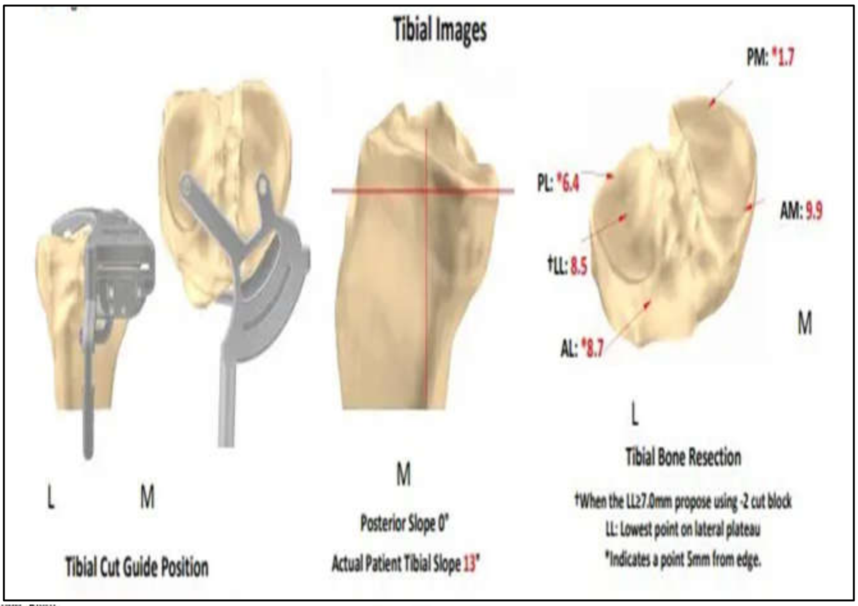
For various types of knee implant case studies and their respective materials and methodologies derived from hospital patient data.

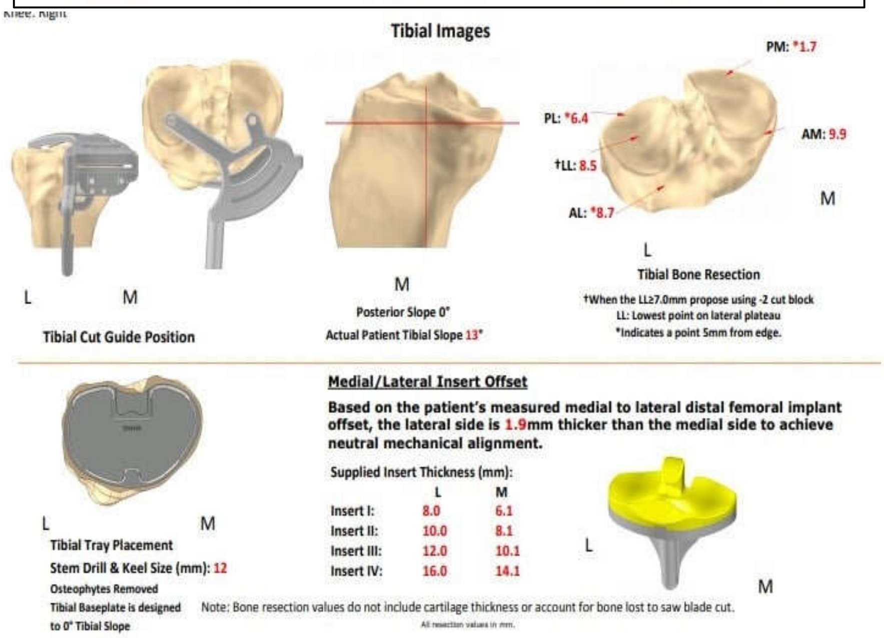
Case study 1

Case Study: Right Total Knee Arthroplasty – 51-year-old male, Weight- 75kg and Load- 0.735 KN

Arthroscopies, one of which was in 2008 as well as another in 2010, both performed by two different physicians. Student claimed that he recalled sustaining an occupational injury while working as a Factory labourer. Patient recalled transporting a pallet which slid off a storage platform and landed on his right joint in 2008, causing the first sign of knee discomfort.

Fig 4 Right Total Knee Arthroplasty





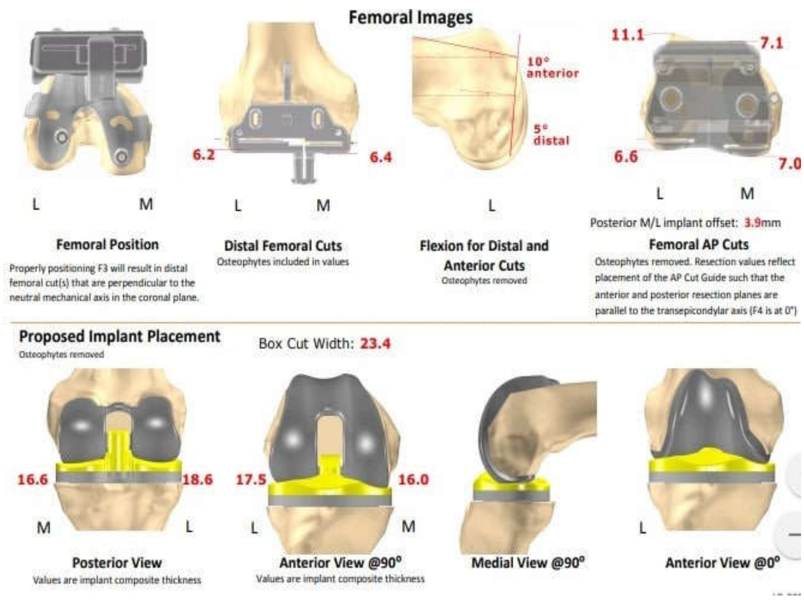


Fig 5 Femoral Images at Different Angle

The patient received an effective Right The sum Knee It employing a conforMIS technique. The post-operative film disclosed the patient has undergone a complete replacement of the knee on his right knee. There is adequate implant positioning. There is no relaxation. No acute fracture exists. The enlargement of soft tissues correlates with the recent surgical procedure. Six weeks of postoperatively ambulatory physical rehabilitation, including flexibility in freedom and strengthening, were provided to the patient. The subject returns for a three-month follow-up alongside full load carrying, a significant range of action, and a pain rating of 0/10. The patient claims that he is now enabled to take his dog on lengthy walks and started to work a part-time as an administrative assistant in the storage area. The individual in question has to move around, get up, and sit for lengthy amounts of time while experiencing no feeling of pain or discomfort. Patient continued to receive necessary care.

Case study 2

Case Study: A 73-year-old male had a customized left total knee replacement, Weight-80 kg and Load-0.784KN

A 73-year-old man came in claiming to have knee pain. discomfort on both sides, with the left side being more severe. The patient's discomfort started around 6 years ago and has been progressively worse since then. Four years ago, he underwent meniscal surgery, although it did not help much. For the last six months, he'd been dealing with steadily worse discomfort that prevented him from going about his normal routine.

According to the patient, there was no traumatic event or twisting injury that precipitated the discomfort. He said he wasn't feeling shaky or weak. The discomfort felt at the inside aspect of both knees eventually spread throughout the joint. Stairs, long walks, turns, twists, bending, kneeling, and squatting all made the agony much worse. The agony was pain that's hard to pin down.

Fig Preoperative X-ray showing the AP and lateral views of the left knee

After careful consideration of the patient's needs and comorbidities, He received a recommendation to undergo a customized left complete replacement of his knee. Risks, advantages and other options were dealt with in depth with the person receiving treatment. The subject consented to undergo surgery.

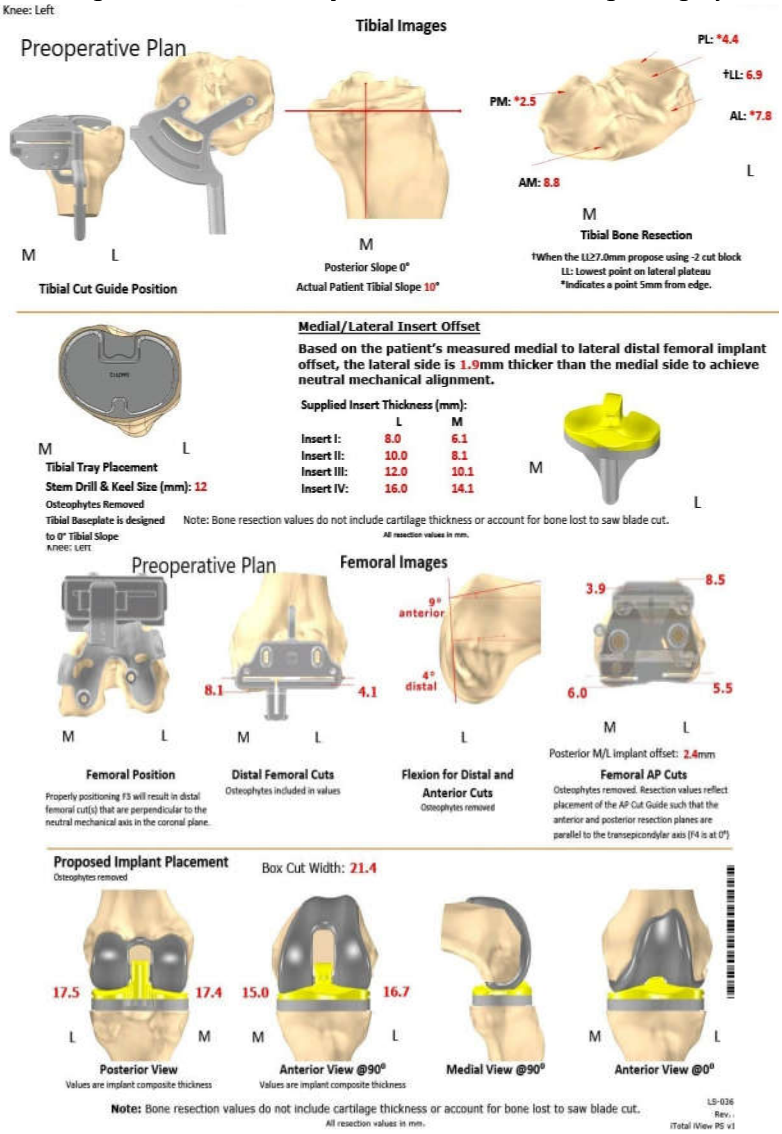


Fig 6 Femoral Images at angle

As portion of this procedure's setup, a preliminary CT image was taken. The data obtained from the scan was utilized to obtain accurate information about The anatomy and biomechanics of the person being treated. Devices and bone-cutting devices were created specifically for the individual receiving them. A preliminary strategy has been created to direct a surgical step.

Surgery: Left complete knee replacement.

Implants Used: Unique tibial receptacle with the help of a femur prosthesis that has a 32-mm metal stem and a 6-mm plastic insert kneecap.

Case study 3

A 72-year-old male had bilateral custom total knee replacement. Case Study, Weight- 70 Kg and Load- 0.686 KN

A 72-An elderly male patient of ours (6 years!) has been coming in complaining of knee discomfort on both sides. Those afflicted with the disease was a retired construction worker**.** He had been in construction for the past 40 years. He was currently staying with his son and loved to ride bicycles and walk his dog.

The pain was first noticed 8 years ago having an insidious onset. The patient feels his long career as a construction worker has led to arthritis in his knees. His construction work involved bending, pushing, pulling, twisting, and lifting of heavy objects.

Fig 7 Preoperative AP and radiographs of the left knee taken from the side.

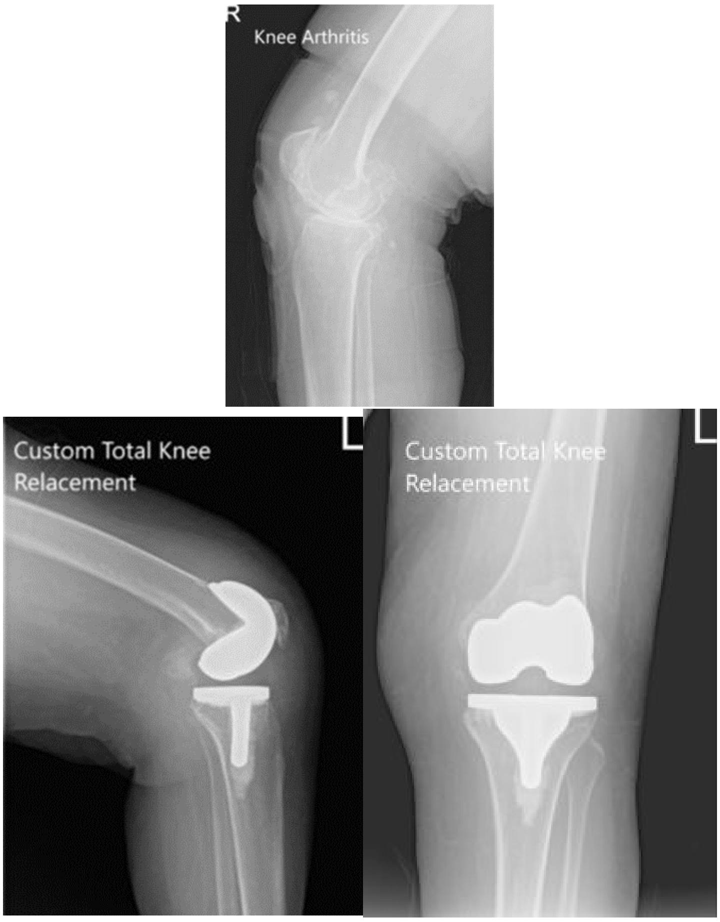


Fig 8 Knee X-rays taken after surgery, both from the front and the side joint

For protection against thrombosis of the deep veins, he was prescribed aspirin 325 mg x 3 months. He had the ability to get around alongside assistance the same day as his operation. The discomfort was managed with medicines. Physiotherapy was initiated for the person's full range of mobility and strengthening of the muscles. The sutures were taken out without incident. The client experienced no pain and full spectrum of movements at the eight-week follow-up appointment. He had returned to his normal activities. He became now ecstatically able to play with his grandkids and ride his bicycle.

Case study 4

Case Study: Female, 68 years old, has a bespoke total knee replacement, Weight- 85 Kg and Load- 0.833KN

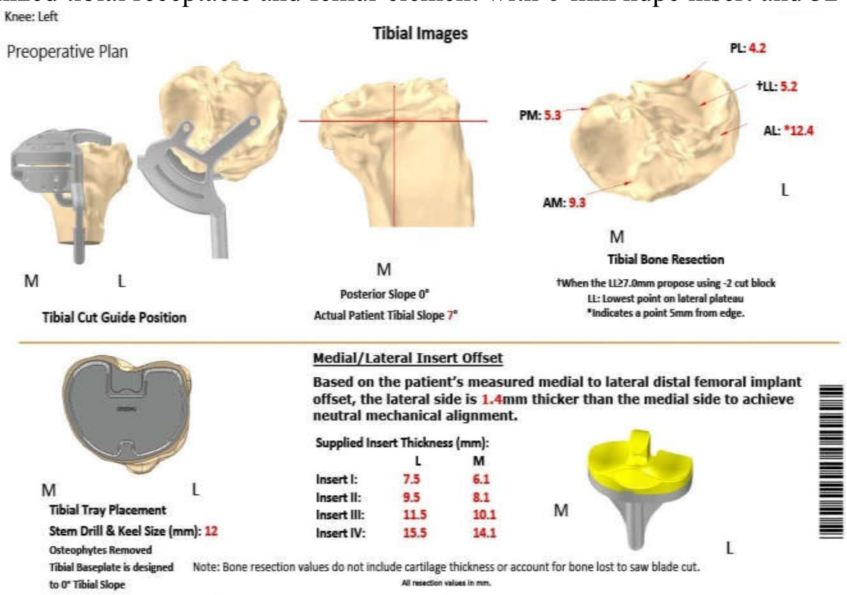
A woman, 68 years old, came into our medical facility complaining of a 12-year history of left knee discomfort. The person in question received a left knee injury while interacting with her children. Doctors advised her to take a prudent approach to her discomfort in her knee. The agony possessed while intensified and become consistent.

Exercises, ice and heat packs, and treatment with lasers provided temporary pain relief for a period of time. The agony went back and knee cortisone injections provided only minimal alleviation. Her doctor informed her that she needs a complete replacement of her knee.

She had worked as a shop manager for several years before retiring. She liked to keep her body moving, particularly by bicycling and walking. She had been bedridden for the last several months, unable to go on walks or do her regular chores.

Fig 9 Left knee AP, lateral, and merchant views taken before to surgery.

Operation: Left total knee arthroplasty.
Prosthesis: Customized tibial receptacle and femur element with 6-mm hdpe insert and 32-mm patella.



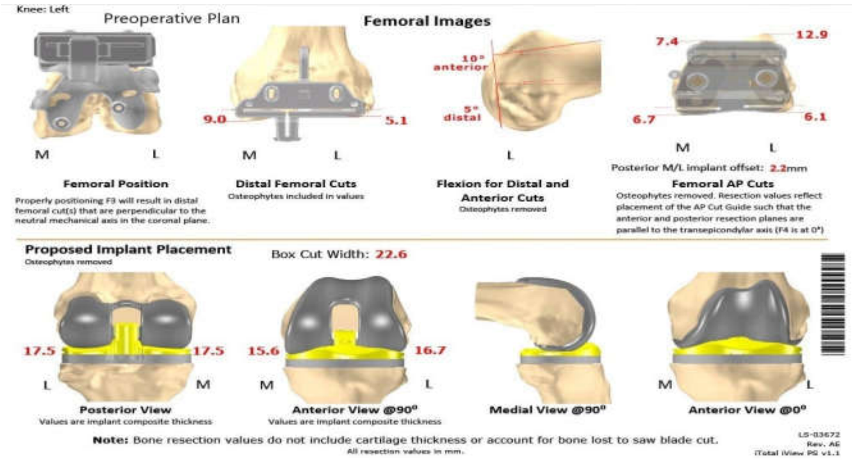


Fig 10 Femoral Images at angle

The day after the operation, she was capable of stroll with assistance. Her medical records kept stable; therefore, she was discharged on that day. Her distant neural condition was unimpaired. Salicylate was prescribed for the prevention of deep vein thromboembolism.

The staples were removed without incident. She had the ability to take steps with assistance after eight weeks of treatment and felt no discomfort. Physical rehabilitation proceeded. The actress had full range of movements or had resumed her regular routine. She was very happy with her surgical result.

Results from Hospital Case Study

i. From postoperative day 2 (POD2) onwards, patients were instructed to do continous passive motion from 0 to 60 degrees, then from 0 to 90 degrees, and lastly from 0 to maximal flexion as tolerated. After surgery, patients were cleared to resume full activity right away.His function score from the Knee Society was 70, and his knee score from the KS was 73 on both sides. This man's OKS (Oxford Knee Score) was a 40.

ii. Considerable prevalence of TKRs in ochronotic arthritis. It is possible that preoperative echocardiography useful for predicting the occurrence of such problems.

iii. Knee disarticulation is preferable to trans-femoral amputation before surgery for a number of reasons. Even if you already have a whole knee end prosthetic, this holds true. After a total-knee end prosthesis is partially removed, this case report shows that distal end bearing is achievable.

iv. After a routine operation, the patient's Right Total Knee Arthroplasty went well. The Film Documentary Outcomes of the Operation Clinically, the patient has just had a complete knee replacement on the right side. After surgery, the patient had 6 weeks of outpatient physical therapy, during which time she worked on her returned for a follow-up visit reporting no discomfort, complete weight bearing, and a significant increase in range of motion.

Experimental Results

Ultimaker Cura

The use of Ultimaker 3D printers is expanding rapidly in a wide variety of fields, such as architecture, engineering, and medicine. Inspiringly, they are already being actively utilized by healthcare practitioners to do anything from educate patients about their disease to design intricate procedures utilizing the models as a guidance during the actual surgery.[62]

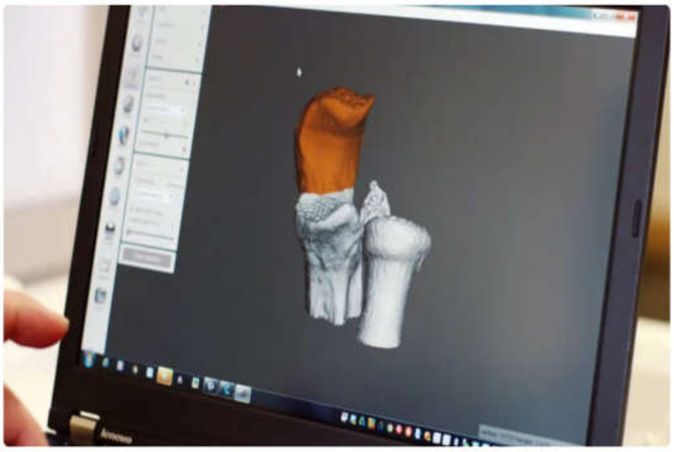


Fig 11 Ultimaker 3D printers[62]

Cosmetic surgery planning is just one area where doctors are finding significant use for 3D printing. Hospitals providing care to critically ill patients are now investigating the possibility of 3D printing.

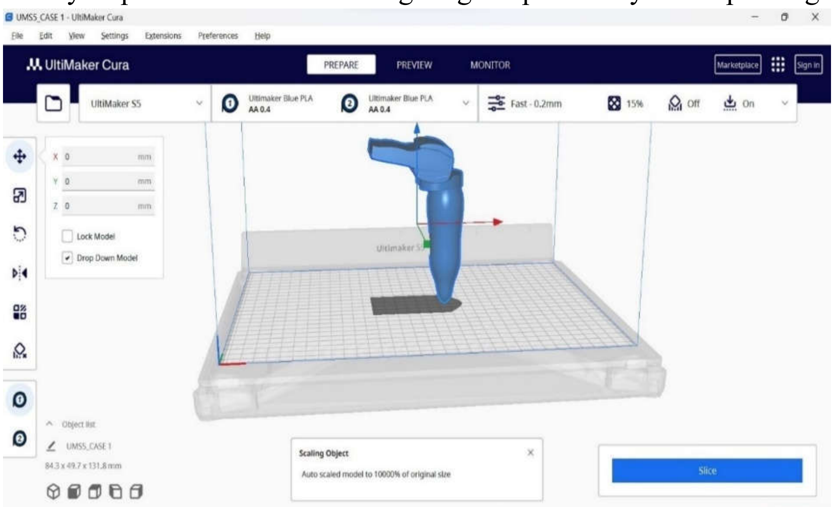


Fig 12 Importing of CATIA Model in 3D Printer Software [51]

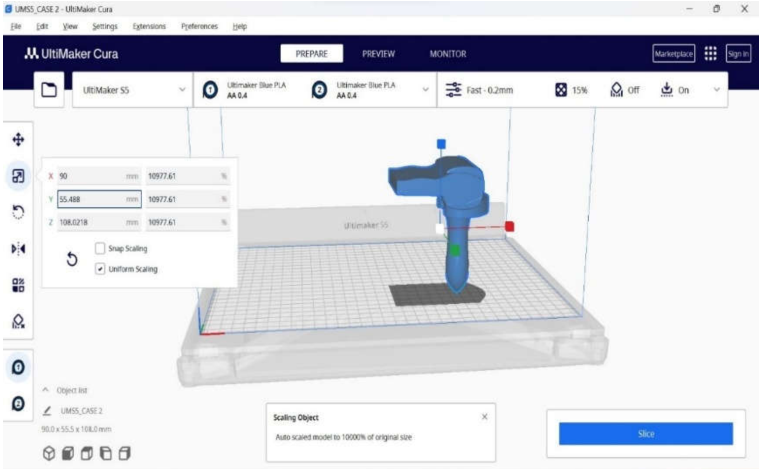
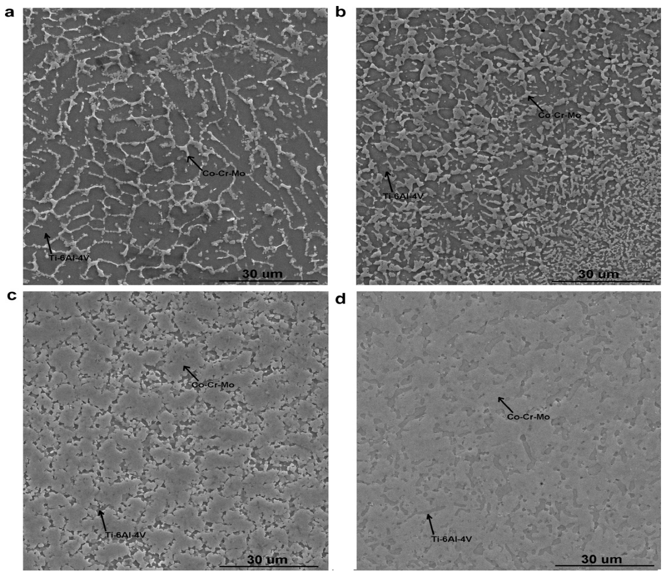


Fig 13 Process of assigning boundary layout [51]

Hardness Testing

Complex alloys may be made using LENSTM (Laser Engineered Net Shaping is additive manufacturing technique for building metallic parts) how the elements used have been melted or pulverized, they are physically and have a similar microstructure to alloys made from pre-alloyed granules. However, the amount of light energy necessary for biochemical consistency in composite elemental mixtures is greatly impacted by factors such as the laser absorbing factor, boiling point, quantity, and entropy of alloy material blending. It is demonstrated that the electrical cost linked to the use of element mixtures is considerably greater than the one related with an use for pre-alloyed granules of the exact same metal. The compressive yield strength of Ti-6Al-4V alloy was 823 MPa (0.823 kN/mm^2) and compressive yield strength of CoCr material was obtained as 612 MPa which was tested on UTM. The load applied was in kN with minimum range of 50 kN and maximum range of 1000 kN.

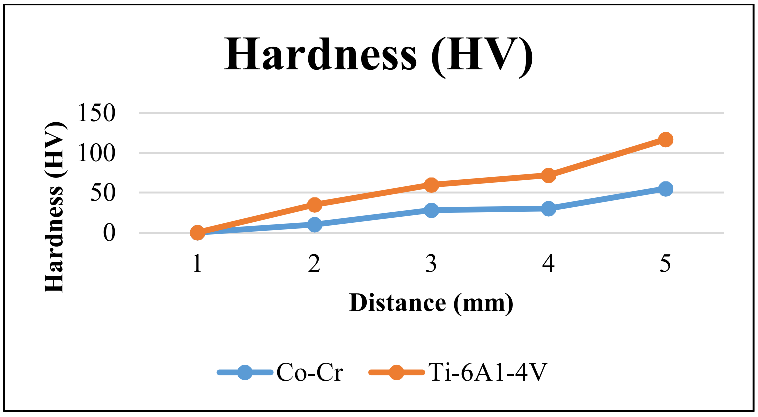


Top surface microstructures of gradient samples with varying concentration of Co–Cr–Mo alloy in top layer: (a) 25%, (b) 50%, (c) 70% and (d) 86%. The phase with the darker contrast is Ti–6Al–4V and that with the lighter contrast is Co–Cr–Mo alloy.

The LENSTM method has been used to effectively install robust and wear-resistant Co-Cr-Mo alloy graduated coatings on Ti-6Al-4V alloy. This technique also has the inherent ability to construct graded structures, using or without openness on one side of the structure, to promote cell ingrowth. Surface hardness increased from 333 HV to 947 HV by increasing the Co-Cr-Mo composition of the top barrier of graded coatings. All coatings were proven to be non-toxic since they supported twice as many living cells as a clean.

Table 5 Hardness of Co–Cr & alloy structures

Element	25%Coalloy	50%Coalloy	70%Coalloy	86%Coalloy
Ti	63.20	42.32	24.19	8.17
Al	5.79	3.29	3.58	4.22
V	3.64	2.35	2.75	1.74
Co	20.70	35.33	45.29	54.87
Cr	5.60	14.79	20.67	26.14
Hardness	588±27	670±28	789±38	947±22



Graph 1 Hardness (HV)

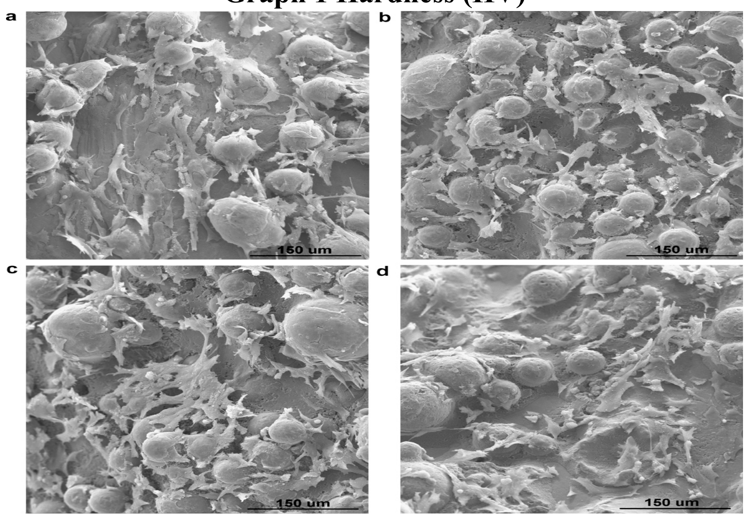
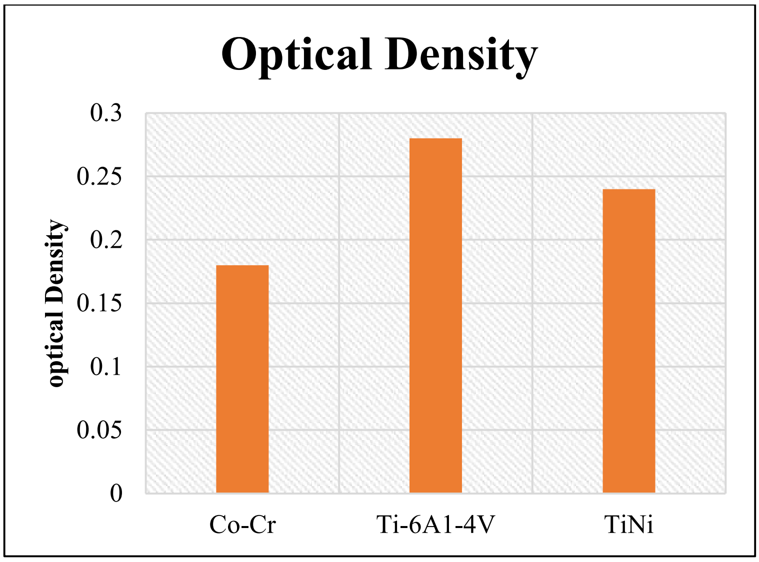


Fig 12 Co-Cr alloy surface concentrations from 0% (Ti-6Al-4V alloy) to 100% (Co-Cr alloy) were applied by laser processing to create these gradient coatings [31]



Graph 2 A greater concentration of live cells is reflected by a higher optical density.

Table.6 Materials for assessing friction and wear

Work piece	Hardness	Roughness (Ra)	Density(g/cm3)
Un-Coated	382 HV	0.30	-
DLC coating	1750 HV	0.36	-
TiN coating	1950 HV	0.30	-
Cryogenic	401 HV	0.30	-
UHMWPE+ CNT 2 %wt	71.7 Shore D	0.19	0.93

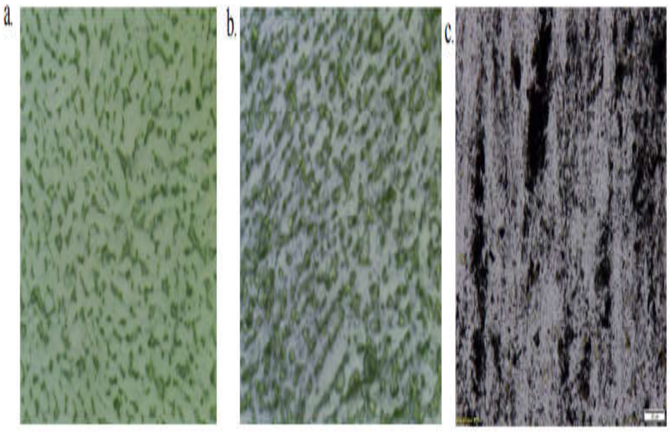
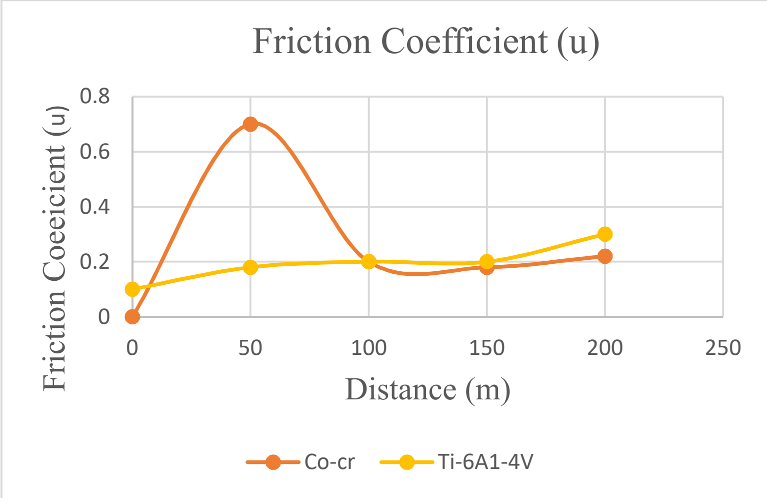


Fig 13 Structure of Ti-6Al-4V; (b) Structure of 24 hr.-cryogenic treatment substrate Ti-6Al-4V (c) Dispersion of Carbon nanotube in UHMWPE [31]



Graph 3 All experimental surface treatments' friction coefficients vs sliding times Pins Ti-6Al-4V vs UHMWPE + 2% CNT disc

The wear experiments carried out three times for each specimen for reducing the experimental errors caused by the porous surface. During human joint movement, a small amount of clear light-yellow liquid, called joint synovial fluid, is present in the joint cavity. This fluid is a mixture of plasma dialysate and synovial cells. The joint synovial fluid can provide nutrition, lubrication of the articular cartilage and protection of joints from mechanical damage. It is vital to study the properties of the artificial joint materials under plasma lubrication condition. In this study, a set of dry friction tests and liquid lubrication of porcine plasma immersed test specimens under the same conditions has been included.

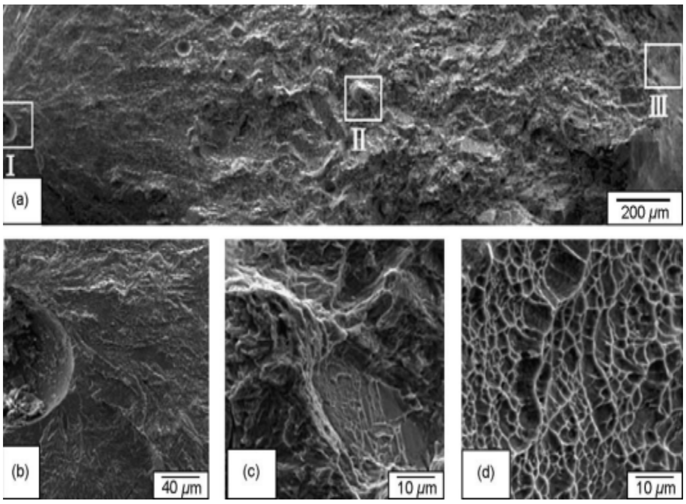


Fig.14 Fatigue fracture surface morphology of Ti–6Al–4V

The starting point of the measuring line was the porous Ti6Al4V surface with high extent of smoothness, and the measuring line was perpendicular to the wear direction. The wearing track was noted to be slightly irregular due to the influence of the porous substrate, and the worn surface of the material presented a regular arc track relative to the substrate. By measuring the grinding degree of porous Ti6Al4V with high-entropy alloy coating under porcine plasma friction condition, three type of the dual coupling bionic structures were analyzed.

In this study, it was revealed that porous Ti6Al4V could effectively eliminate the stress shielding caused by the large modulus difference between the metals and human bones, and the high-entropy alloy coating on the porous Ti6Al4V surface significantly reduced the friction coefficient. The results indicated that the friction coefficient could be reduced by the combination of appropriate pore size and high-entropy alloy film.

Statistical Evaluation
1. Knee cap model geometry

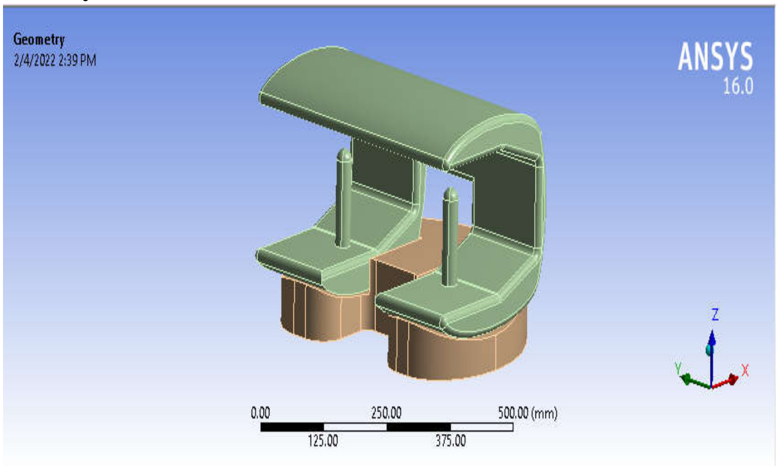
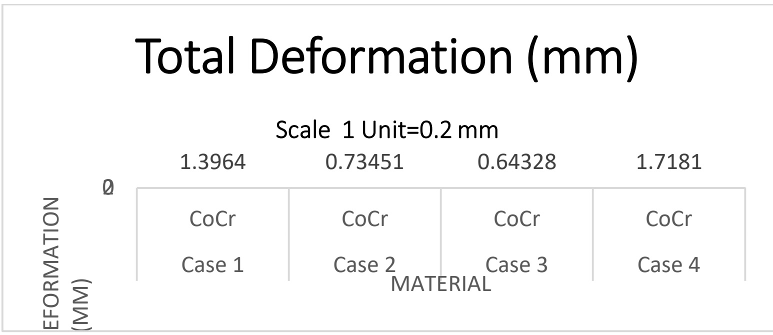


Fig 15 Geometry of knee cap model [51]

Analytical Results and Findings
Results for Case studies for Co-Cr, Ti6Al4V & NiTi Materials
Static Structural Analysis (CoCr)
1. Total Deformation (mm)

Table7 Results for Case studies for Co-Cr Material

Time	Total Deformation (mm)			
	Case 1	Case 2	Case 3	Case 4
	CoCr	CoCr	CoCr	CoCr
1 Sec	1.3964	0.73451	0.64328	1.7181



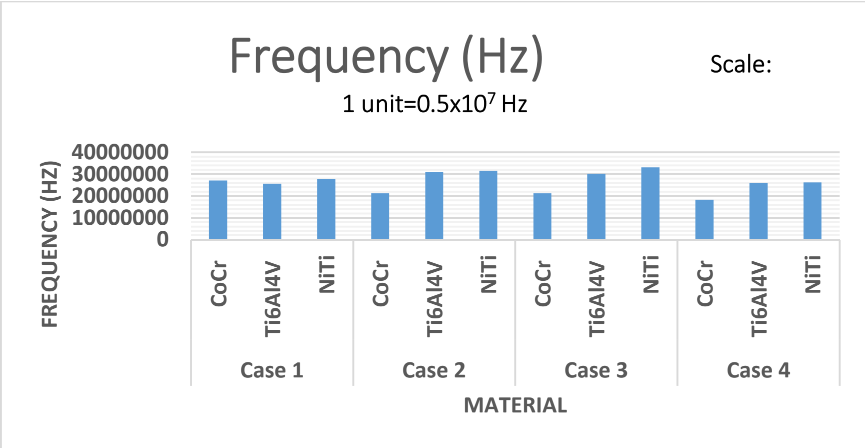
Graph 4 Total Deformation (mm) [51]

As per the graph 7.1, shows results of total deformation for materials CoCr for case 1 case 2 & case 3, maximum deformation in case 4 for material CoCr.

Modal Analysis

Table 8 Frequency (Hz)

Mode	Frequency (Hz)											
	Case 1			Case 2			Case 3			Case 4		
	CoCr	6Al4V	NiTi	CoCr	i6Al4V	NiTi	CoCr	i6Al4V	NiTi	CoCr	i6Al4V	NiTi
	7x10^7	.6 x10^7	8 x10^7	1 x10^7	90 x10^7	15 x10^7	1 x10^7	2 x10^7	3 x10^7	8 x10^7	90 x10^7	3 x10^7



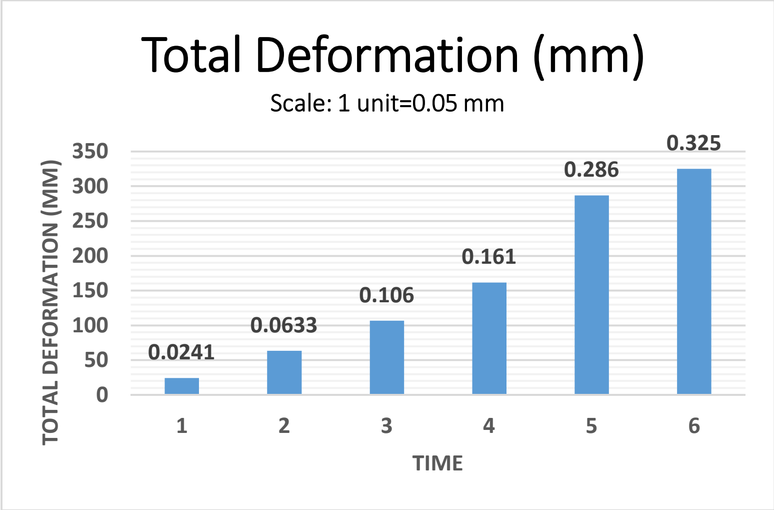
Graph 5 Frequency (Hz) [51]

As per the graph 7.22 shows results of Frequency for materials CoCr and Ti6Al4V for case 1 case 2 & case 3, maximum Frequency in case 2 for material Ti6Al4V and minimum Frequency in case 4 for material CoCr.

Modal Analysis results

Total Deformation of knee cap model

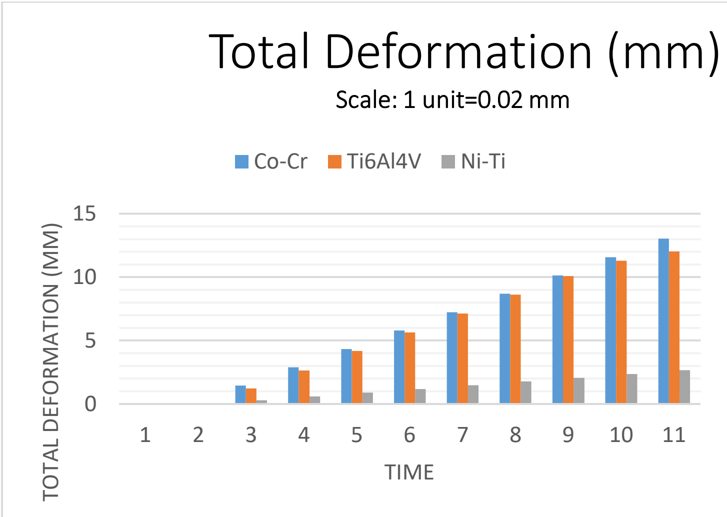
(Measuring range for the graph is from 0 mm to 0.350 mm)



Graph 6 Total Deformation of knee cap model in modal analysis [51]

The graph 7.23 shows Total Deformation in mm of knee cap model for material Co-Cr for the model. As we can see that Co-Cr material has the Total Deformation ranges between 0-0.350 mm. Maximum deformation for CoCr material is 0.325 mm for 6 second of analysis.

Comparison of knee cap models made for 3 materials respectively
Total Knee Cap Deformation Model
(Measuring range for the graph is from 0 mm to 0.140 mm)



Graph 7 Total Knee Cap Deformation Model [51]

The graph 7.26 shows Total Deformation in mm of knee cap model for 3 different materials like Co-Cr, Ti6A14V and Ni-Ti for the model. As we can see that Co-Cr material has the highest Total Deformation which is 0.1302 mm. After that Ti6A14V has lower Total Deformation than Co-Cr material which is 0.1202 mm. And Ni-Ti has the lowest Total Deformation value which is 0.0266mm.

Comparative Analysis of all seven parameters is not added in the paper as it will acquire more space.

Findings

Comparative results of knee cap model with CoCr, NiTi and Ti6Al4V materials for 4 case studies

i. According to the graph 7.1 and 7.8 which displays the findings of total deformation for materials CoCr and Ti6Al4V for cases 1, 2, and 3, the material CoCr experienced the most amount of distortion in case 4, while the material Ti6Al4V experienced the least amount of deformation in case 1.
ii. According to the graph 7.2 and 7.9 which displays the results of the equivalent elastic strain for the materials CoCr and Ti6Al4V the maximum equivalent elastic strain for the material CoCr was seen in case 4, while the minimum equivalent elastic strain for the material Ti6Al4V was seen in case 1.
iii. According to the data presented in the graph 7.3 and 7.10 which compares the Normal Elastic Strain of the materials CoCr and Ti6Al4V for cases 1, 2, and 3, the material CoCr exhibited the highest Normal Elastic Strain in cases 3 and 4, while the material Ti6Al4V exhibited the lowest Normal Elastic Strain in case 1.
iv. According to the graph 7.4 and 7.11 which displays the results of Shear Elastic Strain for materials CoCr and Ti6Al4V for cases 1, 2, and 3, for materials CoCr and Ti6Al4V.
v. The results of the Equivalent Stress for the materials CoCr and Ti6Al4V are shown in the graph 7.5 and 7.12 for cases 1, 2, and 3. The graph indicates that the greatest Equivalent Stress for the material CoCr occurs in case 2, while the least Equivalent Stress for the material Ti6Al4V occurs in case 4.
vi. According to the graph 7.6 and 7.13 which depicts the results of normal stress calculations for the materials CoCr and Ti6Al4V for cases 1, 2, and 3, the material CoCr experienced the highest normal stress in case 4, while the material Ti6Al4V experienced the lowest normal stress in case 1.
vii. According to the graph 7.7 and 7.14 which displays the findings of shear stress for the materials CoCr and Ti6Al4V for cases 1, 2, and 3, the material CoCr experienced.

Conclusion and Future Scope

Conclusion

Using CATIA software, the design methodology for a tibial and femoral implant component has been developed in this study. A knee joint's static analysis has been performed using the ANSYS software by incorporating the contact pair between the components. In this investigation, static and modal analysis was performed on three distinct materials: Co-Cr, NiTi, and Ti6Al4V. Also considered in this investigation were the four case studies and three distinct materials: Co-Cr, NiTi, and Ti6Al4V.

To prevent permanent immobility in patients with arthritis or accident-related joint injury, a total knee prosthesis is required. According to the results of the analysis, decreasing the longitudinal radius of the TKR design decreases the shear tension, thereby reducing wear. As a result, the costs associated with enhancing knee joint treatments are reduced. In addition, the results indicate that NiTi material is stronger than ordinary polyethylene. In this Nickel titanium material, the total displacement is less than that of other materials. Therefore, NiTi is an effective material for Knee joint replacement.

Social Benefit:

From this research work, by performing modelling on CATIA and performing stress and strain analysis under varying conditions in ANSYS, the social benefit obtained is the assembled knee cap model will be available to the patient in which varying and increasing weight of the patient, cost effectiveness, biocompatibility, etc., so as to avoid repetition of surgery.

Future Scope

i. The analysis will be done for deep flexion angles for varying degrees of freedom.
ii. Thermal stresses at high temperature will be investigated as no work is done on change in temperature.
iii. Different orientation of carbon fibers in polyethylene matrix can be considered for further evaluation which will be helpful to get light weight material with good strength and stability.
iv. The results of analysis of femorotibial joint of a particular material combination will be verified by using a knee simulator which triggers the force and load application similarly as the knee parts moves in all varying degrees of freedom.

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