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# Analysis of Artificial Support Structure for Knee Joint: A Review

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*Abstract:* **This article is to develop a specialized artificial support structure for knee joint by sustaining not only knee joint load but also ankle joint load which is transfer to knee joint and also to give strength to tibia to reduce pain of patient and to reduce effort for work after total knee replacement surgery. In presently available brace, they only concentrated on knee joint loading and neglecting other loads such as load transfer from ankle joint to knee joint. Loading on knee joint is controlled then life of components and total knee replacement will be increased. To reduce stress on knee joint bracing is need to be introduced after the total knee replacement surgery, so that it should sustain all the external stress and loads without dislocation of brace for perfect alignment. Artificial support structure for knee joint model is generated in the software, "Creo Parametric 2.0" by developer PTC inc. Generated model is then exported to ANSYS 14.5 software for analysis. 6 materials are analysed on ANSYS.**

*Keywords:* **Total Knee Replacement Surgery, Artificial Support Structure, Knee Joint, ANSYS.**

## I. INTRODUCTION

Biomechanics is a scientific discipline which applies principles studied in mechanics to the understanding of living organisms. This discipline incorporates researchers from fields such as biophysics, bioengineering, biology, and medicine, and covers organisms from plants to whales. Biomedical Engineering blends traditional engineering techniques with biological sciences and medicine to improve the quality of human health and life. The discipline focuses on understanding complex living systems - via experimental and analytical techniques - and on development of devices, methods and algorithms that advance medical and biological knowledge while improving the effectiveness and delivery of clinical medicine. Biomechanics is also used to show people how to use their bodies more efficiently, as in the case of a massage therapist who uses the pressure of elbows instead of just the hands. Biomedical engineers may work in hospitals, universities, industry and laboratories. There are range of possible duties, including the design and development of artificial organs, modelling of physical processes, development of blood sensors and other physiologic sensors, design of therapeutic strategies and devices for injury recovery, development and refinement of imaging techniques and equipment, development of advanced detection systems, testing of product performance, and optimal lab design.

Bones are rigid organs that constitute part of the endoskeleton of vertebrates. They support and protect the various organs of the body, produce red and white blood cells and store-minerals. Bone tissue is a type of dense connective tissue. Bones come in a variety of shapes and have a complex internal and external structure, are lightweight yet strong and hard, and serve multiple functions. One of the types of tissue that makes up bone is the mineralized osseous tissue, also called bone tissue, that gives it rigidity and a coral-like three-dimensional internal structure. There are four types of bones in the human body:

i) Long bone
ii) Short bone
iii) Flat bone
iv) Irregular bone

## II. KNEE JOINT

The knee is one of the largest and most complex joints in the body. The knee joins the thigh bone (femur) to the shin bone (tibia). The smallest bone that runs alongside the tibia (fibula) and the kneecap (patella) are the other bones that make the knee joint. The knee is a mobile troche-ginglymus (a pivotal hinge joint), which permits flexion and extension as well as a slight internal and external rotation. The knee is a complex system of tissues that provide mobility and support to the body. It experiences different types of motion as a whole system or relative to its parts and is therefore subjected to a variety of loading conditions as a person walks, runs, or performs any other type of load-bearing activity. In the knee joint, a set of muscles and ligaments joins three bones (the tibia, the patella and the femur) and controls the range of motion of the knee.

The knee is a hinge type synovial joint, which is composed of three functional compartment: the femoropatellar articulation consist of the patella, or “kneecap”, and the patellar groove on the front of the femur through which it slides and the medial and lateral femur as shown in Figure 1.

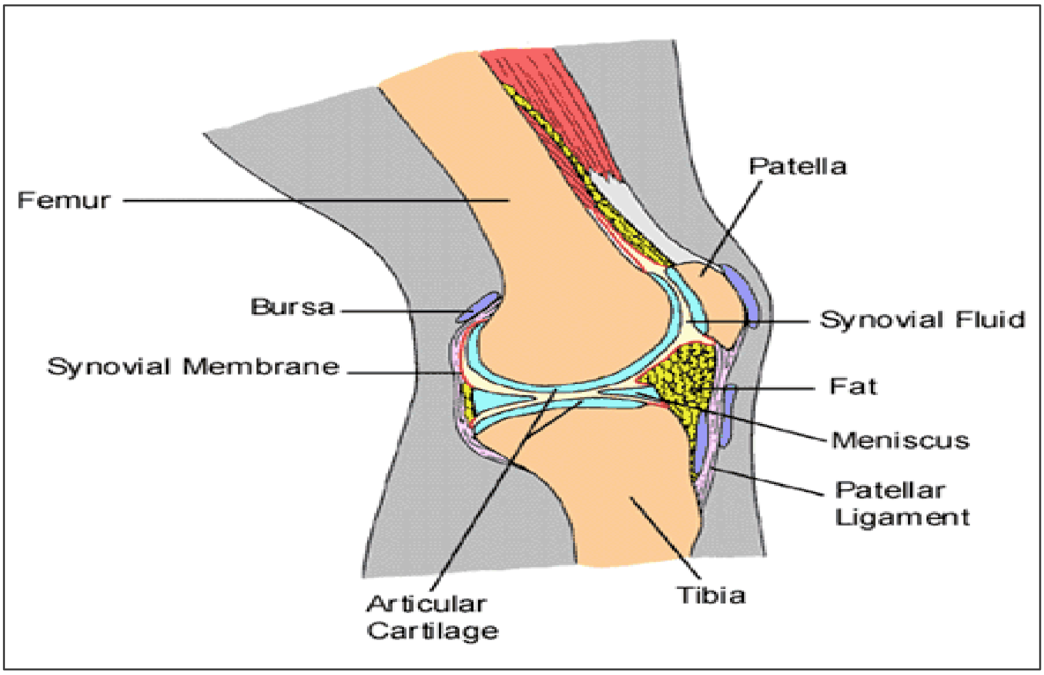


**Figure 1. General Anatomy of Knee Joint**

### A. Knee Biomechanics

The knee is an important consideration in the study of biomechanics because it is one of the most commonly injured areas of the body and is susceptible to degenerative joint diseases. The knee joint joins the femur, tibia, and surrounding supportive muscle and ligament groups [3]. The inferior femur has lateral and medial femoral bulbs, or condyles, that rest on the concave tibial condyles of the superior tibia. Cruciate ligaments hold the femur and tibia together, and additional muscles and ligaments serve to stabilize the knee [6].

Anatomical considerations for this report will be limited to bone and cartilage components of the knee, as those are the main players in the occurrence of wear. Both the superior tibia and inferior femur have a covering of cartilage. This layer of cartilage, known as the meniscus, separates the bone surfaces. Motion in joint is supported on a thin fluid film that sits atop the cartilage layer, which leads to low wear and friction in the healthy knee [6]. The most identifiable component on knee anatomy, the patella (or kneecap), is connected with patellar ligaments that aid in extension of the knee joint.

### B. Treatment: Total Knee Replacement

There are various types of knee replacement surgery, which range from partial procedures that treat one or two compartments in the knee to total knee replacements that address all three compartments. Knee implants, shown below, serve as replacement for removed portions of the femur, patella, and tibia. There are over 150 knee implant designs on the market today, so implant design can vary significantly from one manufacturer to the next [1]. All knee replacements, whether partial or total, are designed so metal components articulate against plastic components, resulting in minimal wear. The metal components consist of titanium or cobalt/chromium-based alloys while the plastic components consist of an ultra-high molecular weight polyethylene. The metal femoral component curves around the condylar surfaces of the femur. The interior groove enables the kneecap to move up and down when the joint bends and straightens. The tibial component is a cushioned platform that is stemmed for implant stability. The metal stem is topped with a polyethylene cushion that acts as the articulating surface.

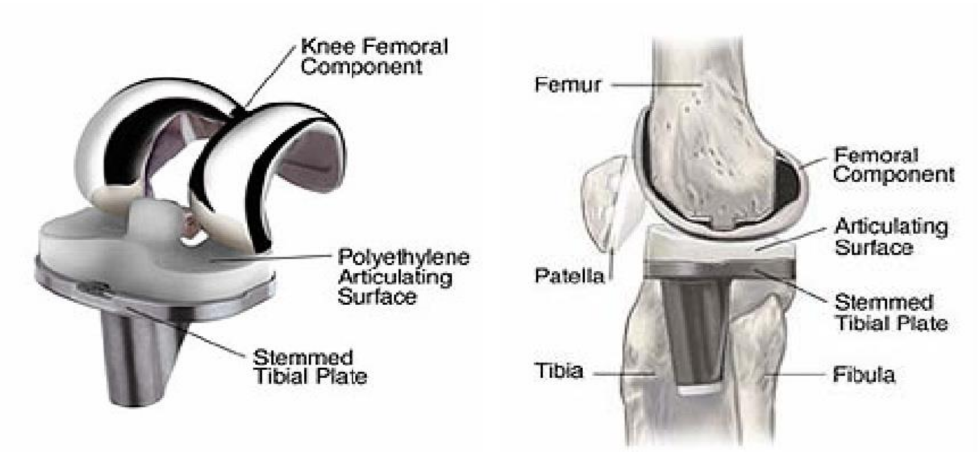


**Figure 2. Total Knee Replacement- Implant Diagrams**

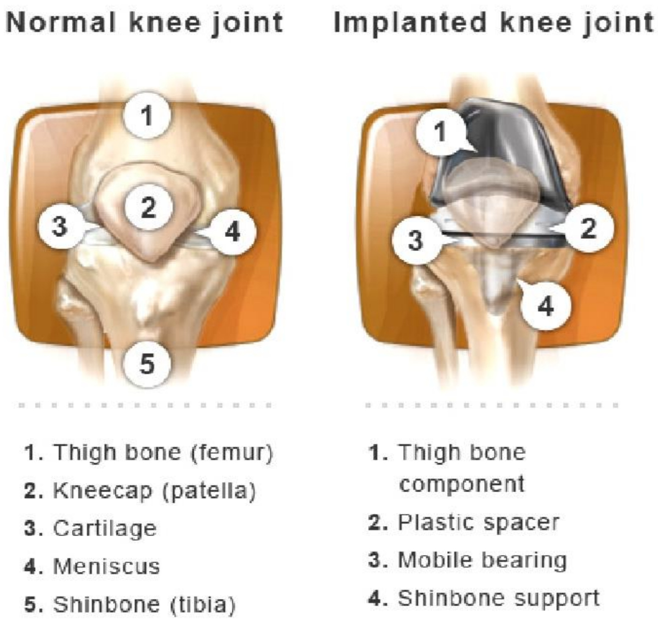


**Figure 3. Anatomy of the normal knee joint and an implanted knee joint**

## III. RESEARCH REVIEW

In current era there are various support structure available for knee joint. But in that design they are only concentrated on knee joint loading. So they can only give sustain load which is affecting to knee joint and neglecting other loads such as load transfer from ankle joint to knee joint. So it leads to breakage of femoral component, patellofemoral joint component and tibial component tends to failure of total knee replacement surgery makes complication in knee joint. In previous design structure, they can only give external support to knee joint, but we are trying to reduce ankle load effect on knee joint so that it reduces pain also to give flexibility to patients to manage its support structure as per the requirement of size of structure to make better result.

The main focus of this article is to develop a specialized artificial support structure for knee joint by sustaining not only knee joint load but also ankle joint load which is transfer to knee joint and also to give strength to tibia to reduce pain of patient and to reduce effort for work after total knee replacement surgery. For this kind of brace which will transfer load directly from ankle joint to thighs i.e. from ankle joint to femur bone.

The knee is a mobile troche-ginglymus (a pivotal hinge joint), which permits flexion and extension as well as a slight internal and external rotation. in severe states of osteoarthritis, surgical treatment of the knee joint is essential not only to relieve the pain, but most importantly to restore the mobility lost due to the degeneration of the cartilage and also to protect the surfaces of the articulating bones from further wear. In total knee replacement systems available today, a major cause of implant failure is wear of the articulating materials. It is therefore essential to study the modes of wear in order to understand better how to resolve this critical problem and to analyze how each of the components, with their material properties, restore the function of the knee. [2]

Valgus-inducing knee brace can compensate for approximately 10% of the external genu varus moment. This compensation appears to be the main biomechanical mechanism that results in a reduction of joint force within the medial joint compartment. This biomechanical effect is an essential requirement for the reduced pain and improved overall function that result from the use of such braces. Orthotic treatment can effectively manage patients at early and middle stages of osteoarthritis or when other treatment methods are not applicable [3]. Stress fractures are caused by either excessive stress placed on normal bone or by normal stress on abnormal bone, but both fracture types are due to the cumulative effect of repetitive low intensity forces on bone[4].

Components fracture is a rare complication after knee replacement, especially in contemporary designs. We report the first case of a fractured femoral component in a cemented Oxford unicondylar knee prosthesis, 9 years after implantation. Factors leading to this rare kind of component failure are discussed. Revision should be warranted in case of unicondylar femoral component loosening, eliminating the risk of component fracture, especially in obese patients.Main reasons for breakage of component are found in studies are poor design of component, improper placement and loosening, all leading to stress rising followed by fatigue failure and breakage of the component. Aseptic loosening of the component, probably due to a localize thinner cement mantle, combined with patients being overweight, led to stress rising behind the fatigue failure [5].

Patellofemoral joint replacement is a successful treatment option for isolated patellofemoral osteoarthritis. However, results of later conversion to total knee replacement may be compromised by periprosthetic bone loss. Previous clinical studies have demonstrated a decrease in distal femoral bone mineral density after patellofemoral joint replacement. It is unclear whether this is due to periprosthetic stress shielding. The main objective of the current study was to evaluate the stress shielding effect of prosthetic replacement with 2 different patella femoral prosthetic designs and with total knee prosthesis [6].

The ankle brace restricted the ankle movement in the frontal plane but no effects on the ankle kinematics were found for the high-top shoe brace. Wearing an ankle brace did increase the ankle plantar flexion moment but there were no changes in knee joint loading. High-top shoes increased both the ankle plantar flexion moment and knee internal rotation moment. Braces can be used to restrict ankle range of motion during walking and running without increasing the load on the knee joint [7].

Stress fractures should be considered when a patient who had a considerable severe deformity of the knee preoperatively complains of foot pain on the affected side. Foot condition including pain during weight bearing and localized tenderness should be checked after TKA in such patients. Contrary to stress fractures at the hip joint, patients with the fracture of the first metatarsal can be treated without surgery [8].

Research review helps in to find the scope of the research or study, in this literature review, found that stress and loads on knee joint cause the failure of total knee replacement surgery and its component. Because after total knee replacement surgery ligaments are very crucial and it take time to reconstruct it. In this condition if sudden loading and stress can cause breakage in ligaments, this will lead to pain to patient. Sudden load also can break the femoral component, patellofemoral joint component and tibial component.

## IV. MODEL GENERATION

Supportive devices, such as a cane, wearing energy-absorbing shoes or inserts, or wearing a brace or knee sleeve can be helpful. Some research studies have focused on the use of knee braces for treatment of osteoarthritis of the knee. They may be especially helpful if the arthritis is centered on one side of the knee. A brace can assist with stability and function. There are two types of braces that are often used. An "unloader" brace shifts load away from the affected portion of the knee. A "support" brace helps support the entire knee load. In most studies, the knee symptoms improved, with a decrease in pain on weight bearing and a general ability to walk longer distances.

**Figure 4. Available Support Devices**

As per the research review and the need of modification in available supporting devices, expected model of artificial support structure for knee joint is generated in CREO 2.0 Parametric (Modelling Software) to support knee joint and ankle joint is shown in Figure 5.

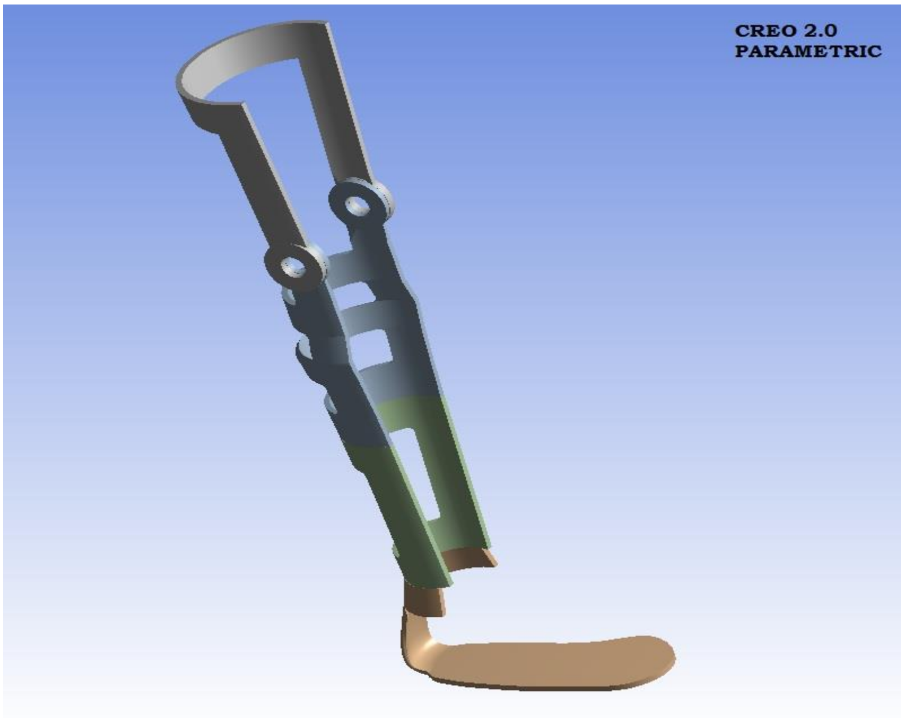


**Figure 5. Model Created by CREO 2.0 Parametric**

## V. CONCLUSION

Previous design structure, supports externally to only knee joint, ignoring load transferred fron ankle joint. So it concludes that, need to develop a specialized artificial support structure for knee joint by sustaining not only knee joint load but also ankle joint load which is transfer to knee joint and also to give strength to tibia to reduce pain of patient and to reduce effort for work after total knee replacement surgery. For this kind of brace which will transfer load directly from ankle joint to thighs i.e. from ankle joint to femur bone. Expected model of artificial support structure for knee joint is generated in CREO 2.0 Parametric (Modelling Software) to support knee joint and ankle joint.

Artificial support structure for knee joint model is generated in the software, “Creo Parametric 2.0” by developer PTC inc. Generated model is then exported to ANSYS 14.5 software for simulation analysis of different loading condition with different materials and alloys. The Design, development, testing and fabrication of artificial support structure has to be standardized on the basis of scientific, logical, analytical and computational methods. The process developed is therefore unique and beneficial to orthopaedic surgeons and patients with knee pain or total knee replacement surgery.

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