

Evaluation of Total Knee Arthroplasty Surgery with Finite Element Analysis

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Introduction: This study aims to demonstrate the importance of the finite element method (FEM) in total knee arthroplasty (TKA) to minimize the necessity for revision.

Materials and Methods: In our study, the TKA system implanted in femoral and tibial bones has been numerically analyzed by three-dimensional FEM. The results and the TKA model have been transferred to 3D SolidWorks 3D software. This study's application aspect focuses on the stress distribution in the interaction between the distal bone portions of the knee joint and the TKA. Our study presents the load distribution on the implants and the demonstration data applied in the standard surgical procedure. The load distribution has also been analyzed, and the degree of valgus was reduced by 3 degrees. This situation helped us to predict early polyethylene corrosion and failure in the future.

Results: As a result, when the valgus angle was reduced by 3°, the load distribution on the implants increased in the medial compartment, especially in the polyethylene insert. This led to the prediction of early polyethylene wear and failure in the future.

Conclusion: FEM emphasizes the importance of biomechanical load distribution during TKA. It is also an excellent method to reduce the incidence of TKA revision and increase patient satisfaction after TKA.

Keywords: Finite element analysis, total knee arthroplasty, polyethylene wear knee

Introduction

The main goals of total knee arthroplasty are to relieve the existing knee pain, reorganize the alignment of the lower extremity, regain the knee joint's movement function, and restore joint stability (1). Although the clinical results of total knee arthroplasty are generally good, the 10-year revision rate has been reported to be 5% in the literature (2). These results are due to

early polyethylene corrosion, malalignment, infection, and aseptic loosening (3). The finite element method studies a complex geometrical structure of the environment offering different properties and the forces acting on it by entering the physical properties of the existing mechanical structures in the computer program and calculating the forces that will act. It also offers modelling of materials regardless of

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whether the materials are homogeneous or heterogeneous or are isotropic or anisotropic. Modelling of materials consists of two stages. These are the pre-processing and post-processing stages. The first stage is the selection of finite elements, and the second stage is the simulation of the stress conditions between the selected materials. As a result, parametric results arise and guide clinicians (4). As a result, it is aimed to reduce the need for revision of total knee arthroplasties as much as possible by systematizing the reasons for revision. The aim is to reduce the need to revise total knee arthroplasties as much as possible by systematizing the reasons for revision.

After saving the bone models scanned by computed tomography, the modelling is often created using programs such as Cosmos, Catia, Abaqus, and especially Ansys. When modeled, the bone object's anisotropy and heterogeneity must be considered. This is important in terms of optimal results (5). Failure to consider the anisotropy of bone leads to misinterpretation of numerical data (6). The prosthesis material applied in arthroplasty is scanned with a microlaser, and a model is created utilizing 3D elements by being integrated into the results of the selected software. In the last part of the software, stress conditions of bone properties and metal properties of the implants used are modelled (7).

The present study aims to minimize the need for revision by demonstrating the importance of finite elements in total knee arthroplasties.

Materials and Methods

Biomechanical factors produced by daily life factors are essential in determining the health and longevity of total knee arthroplasty (8). With the finite analysis method, the mechanical contact between the surface contacts of the prosthesis components is determined numerically (9). FE analysis applied to the bone tissue created in the model allows the calculation of the stress and strain responses of

the forces applied to the structure in the studies conducted (10). On the other hand, this method is also used to predict deformations of musculoskeletal structures and to investigate biophysical stimuli at the cellular level (11).

Designs of modal

Femur and tibia bone sections were scanned by computerized tomography. The results and total knee arthroplasty model were transferred to 3D SolidWorks software (Dassault Systèmes, Vélizy-Villacoublay, France, 2012). The created model is shown in Figure 1.

This study's application aspect focuses on the stress distribution in the interaction between the distal bone portions of the femur and the proximal bone portions of the tibia and total knee arthroplasty. Thus, the stress factors in the distal and proximal parts of the bones in the knee joint were clearly understood. It was sized between 0.3 and 1 mm to ensure the accuracy of the numerical data (12).

Calculating the mechanical data for each system component by numerical analyses based on suitable predefined parameters is possible. To make the results meaningful for the user, different colour gradients appear. These gradients vary from blue to red. The gradient colour appears as red, where the stress points are high. Figure 2 shows the load distribution on arthroplasty (13).

Results

Minimal position changes may have more significant consequences during arthroplasty placement (14). It has been pointed out that knee arthroplasty should be personalized to ensure maximum compliance, and its effect value should be higher (15). Total knee arthroplasty has been shown to have different effects on the muscles in models with and without cutting the posterior cruciate ligament (16). It has been found that 5-10 degrees of malrotation during arthroplasty causes a more significant effect and increased pressure in the medial compartments (17).

The load distribution and demonstration data on the implants applied in the normal surgical procedure are revealed in Figure 2. At the same time, the load distribution was examined with the valgus degree reduced by three degrees. This time, increased load distribution was observed in medial compartment, especially in polyethylene insertion. This is shown in Figure-3. This situation helped us to predict early polyethylene corrosion and failure in the future.

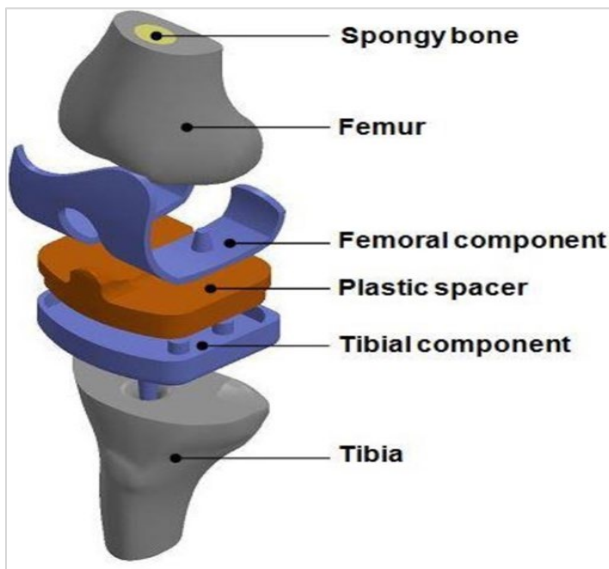


Figure 1. Ansys 3D model of femur, tibia and total knee arthroplasty

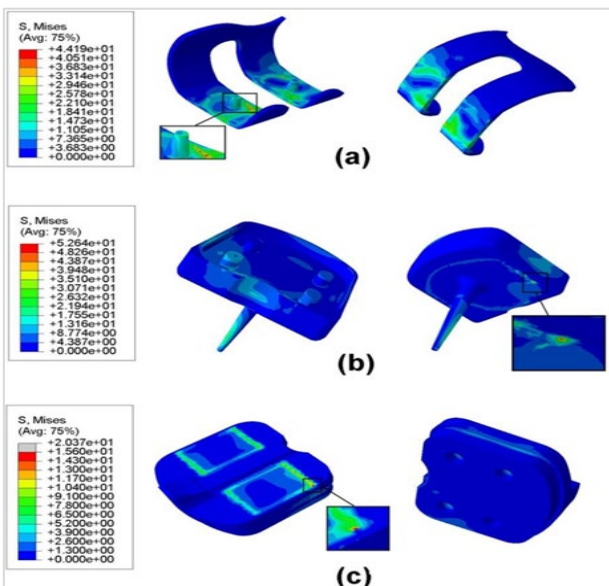


Figure 2. a: Femoral component, b: Tibial component, c: Polyethylene insert

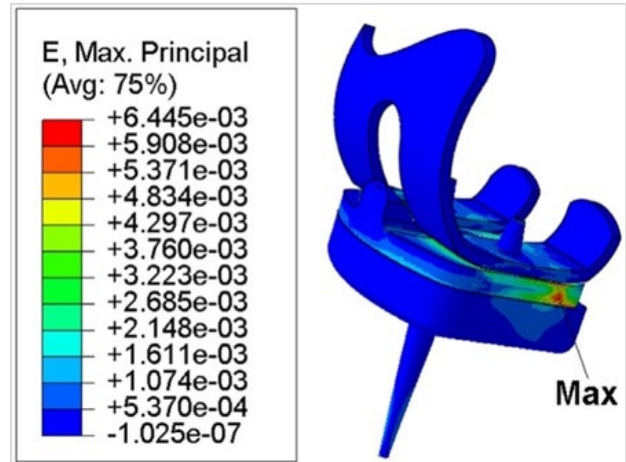


Figure 3. Valgus angle reduced by 3 degrees and demonstration of load distribution in the medial area

Discussion

In orthopaedic surgery discipline, total knee arthroplasty is foreseen to be applied in severe pain and functional failure of the patient. Many clinical studies show that the total knee arthroplasty success rate is high (18-20). However, the failure after arthroplasty surgery is usually biomechanical (21). These factors affect the mechanical stiffness of the components of total knee arthroplasties and the supporting bones, the magnitude of the forces on the restored joint, and the load distribution. As a result, it has been shown that any malalignment will completely change the load distribution on the joint in the applied arthroplasty (22-24). It has also been shown that there will be restrictions on joint movements (25).

Total knee arthroplasty is a core value with sensitive areas for preventing high contact stresses, high wear, and prevention of wear risk (26). Evaluation is performed by finite element analysis to calculate contact pressures and to observe high-pressure areas with a numerical approach to investigate the potential possibility arising from the effect of such combined mechanical loads, to calculate contact pressure, and to observe high-pressure areas with a numerical approach (27). Data supporting the clinic are presented to the literature quickly with this non-invasive method.

In this study, FEM analysis was shown to be effective in stimulating various conditions and complications in total knee arthroplasty. Finite element modelling emphasizes the importance of biomechanical load distribution during total knee arthroplasty. It is also an excellent method to reduce incidence of total knee arthroplasties revision and increase patient satisfaction after total knee arthroplasties.

Conflict of Interest

The authors declared no conflict of interest.

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No financial support was provided from any institution or organization within the scope of the research.

Ethics Statement

Since the present research was completely virtual scanning and is not done on any living thing (human or animal), ethical institution approval is not required.

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