Analele Universităţii de Vest din Timişoara
Vol. LVI, 2012
Seria Fizică

THE INFLUENCE OF COMPONENT ALIGNMENT ON THE LIFE OF TOTAL KNEE PROSTHESES

Delia Bugariu, Liviu Bereteu

"Politehnica" Univ. of Timisoara, Faculty of Mechanics Bv. Mihai Viteazu, Nr. 1, 300222, Timisoara, Romania

Article Info
Received: 28 December 2011
Accepted: 19 February 2012

Keywords: total knee prosthesis, numerical analysis, component alignment.

Abstract
An arthritic knee affects the patient's life by causing pain and limiting movement. If the cartilage and the bone surfaces are severely affected, the natural joint is replaced with an artificial joint. The procedure is called total knee arthroplasty (TKA). Lately, the numbers of implanted total knee prostheses grow steadily.
An important factor in TKA is the perfect alignment of the total knee prosthesis (TKP) components. Component misalignment can lead to the prosthesis loss by producing wear particles.
The paper proposes a study on mechanical behaviors of a TKP based on numerical analysis, using ANSYS software. The numerical analysis is based on both the normal and the changed angle of the components alignment.

1. Introduction

Primary total knee arthroplasty with modern implants results in more than 95% good-to-excellent results. Failure of primary TKA within 5 years has numerous causes, including instability, infection, patients age, body weight, patellar problems, wear, and loosening. [1]

The average lifetime of knee prosthesis is up to 12-16 years. But lately, due to new investigations and designing techniques, this may reach 25 years. To increase life span of the prosthesis, before implantation many factors must be analyzed: the patient's disease, the degree of the joint's affection, the associated affections and the effect that they could have on the prosthetic joint, the age of the patient, body weight, etc. Another very important factor is the fixing of the prosthetic. The preparing of the bone area on which the prosthesis would be fixed is done with specific instruments, specific to any kind of prosthesis. Implant positioning and knee alignment are two primary goals of successful knee arthroplasty [2]. At the end of the surgery, the surgeon checks the way the components slide to one another. It is essential

that between the femoral and the tibial component, the contact to be on the whole surface of the condyles, for the loads to be equally distributed on the medial and lateral condyle of the tibial bone. The ideal contact characteristics of the tibio-femoral joint prosthesis will be changed under the misalignment condition, which can be caused by surgery technique or soft tissues imbalance [3].

This paper proposes a study of the biomechanical behavior of a total knee prosthesis, in case the components are correctly placed, respectively the femoral component is tilted by one degree to the correct position.

2. Method

This study revealed the importance of component alignment of the total knee prostheses in in vitro biomechanical testing.

The proposed prosthesis has three components (figure 1): the femoral component, the tibial component and an intermediate component.

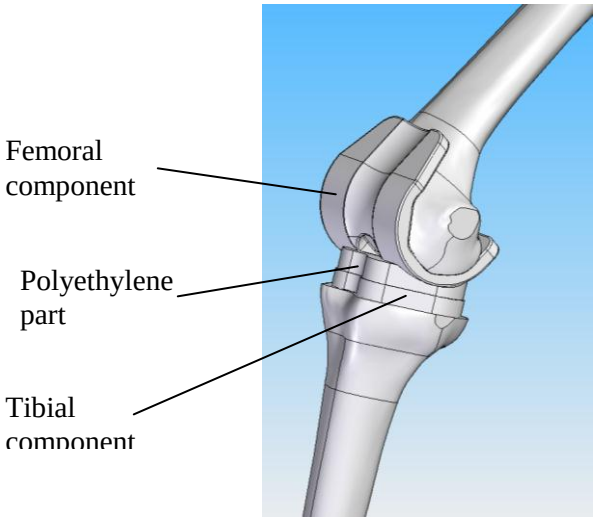


Figure 1: Knee prosthesis - general structure

The prosthesis components have been designed in Solid Edge software and for the finite element analysis ANSYS 12.0 Workbench software had been used. The selected materials are CoCrMo Alloy for the femoral and tibial components and UHMWPE (Ultra-High-Molecular-Weight Polyethylene) for the intermediate part. For the first case the components were assembled in the natural position. For the second case one degree angle was set between femoral component and the polyethylene part.

For the FEA the fixed support was considered on the inferior side of the tibial bone. The application point of the compressive load (figure 2) is on the femoral head**.** The force has

three components: one of 800 N on z axis (vertical), one of 100 N on Y axis and the third one of 50 N on x axis.

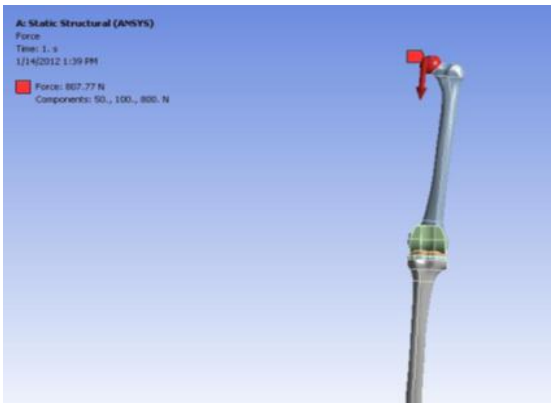
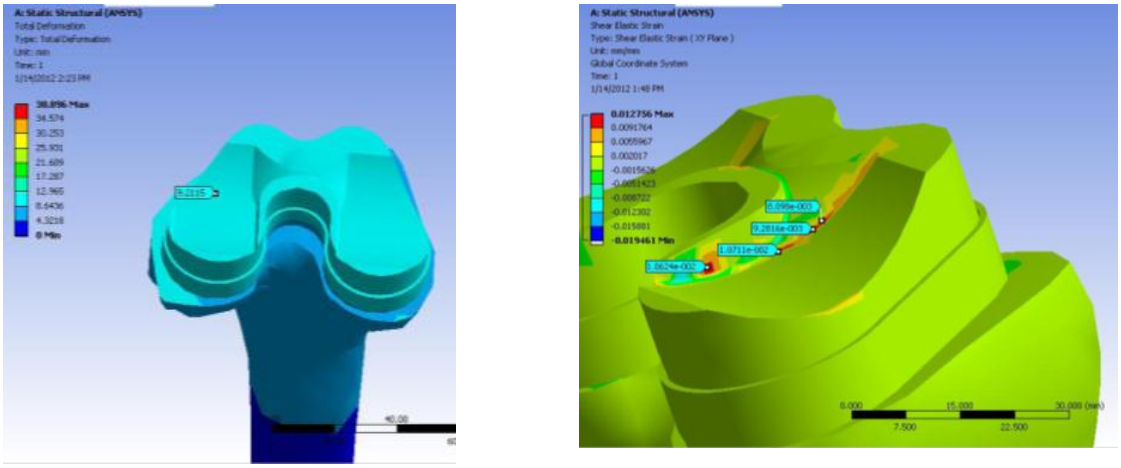


Figure 2: Force components

3. Results and Discussions

To emphasize the importance of the components alignment, the obtained results for both cases will be shown. For the first prosthesis we can see in figure 3 a) that on the polyethylene component, in the tibial condyles area, the stresses are uniformly distributed. In the second case (figure 3 b)) the maximum values of the tensions had been recorded in the medial area.



a) Prosthesis with normal components alignment b) Prosthesis with components misalignment

Figure 3: Stress distribution on the tibial condyles

FEA showed that at the polyethylene component surface the total deformations are between 4.12 mm and 8.26 mm for the first case, and between 2.18 mm and 10.07 mm for the second case. The equivalent elastic strain and equivalent elastic stress obtained in the condyles area are presented in Table 1 (P1- Prosthesis with normal components alignment, and P2- Prosthesis with components misalignment)

Table 1.

	P1	**P2**
Equivalent (von-Mises) elastic strain [mm/mm]	$2.48e^{-4}$; $7.99e^{-4}$	$5.06e^{-4}$; $1.5e^{-2}$
Equivalent (von-Mises) stress [MPa]	$1.9e^{-2}$; 11.28	$1.99e^{-2}$; 50.58
Normal elastic strain [mm/mm]	$-2.45e^{-4}$; $3.57e^{-5}$	$-8.95e^{-3}$; $5.02e^{-3}$
Shear elastic strain [mm/mm]	$-3.33e^{-3}$; $1.27e^{-4}$	$-1.94e^{-2}$; $1.27e^{-2}$

As it resulted from Finite Element Analysis, the component misalignment, affects the mechanical strength of the prosthesis, and can lead to the prosthesis loss by producing wear particles.

Conclusions

The components alignment is an important problem that has to be considered, because it influences the lifetime of the prosthesis. In case that the tensions are not uniformly distributed on the surface of the prosthesis, the stressed areas will produce wear, which leads to the degrading of the intermediate component. It is well known that wear particles lead to the loss of the prosthesis.

The obtained results from the analysis show that tilting by one degree the components leads to a big influence of the tensions distribution on the polyethylene component.

In the future, compression and torsion testing for a knee prosthesis model is required, in the conditions mentioned above.

Acknowledgements

This work was partially supported by the strategic grants POSDRU 6/1.5/s/13 (2008) and POSDRU 107/1.5/S/77265 (2010) of the Ministry of Labor, Family and Social Protection, Romania, co-financed by the European Social Fund – Investing in people.

References

1. D. L. Back, L. David, A. Hilton, G. Blunn, T. W. R. Briggs, S. R. Cannon, The Knee 15 (2008) 40–44;
2. F. X. Koeck, J. Beckmann, C. Luring, B. Rath, J. Grifka, E. Basad, The Knee 18 (2011) 294–299;
3. J. Liau, C.-K. Cheng, C.-H.Huang, Y.-M. Lee, S.-C. Chueh, W.-H. Lo, Clinical Biomechanics, 14 (1999) 717-721.