EFFECT OF SLOPE CHANGES IN POSTERIOR STABILIZER ON THE ROLLBACK MECHANISM OF THE KNEE IN FLEXION-EXTENSION

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ABSTRACT:

A posterior stabilizer role on TKA is to enforce posterior roll back of the femoral component on the tibial surface and to prevent posterior subluxation of the tibia. Femoral cam engages with the tibial post at high flexion angle. The articulation of the femoral cam with the tibial post is studied through finite element method to describe the rollback mechanism and the posterior displacement of the femoral contact points in the condylar surfaces are compared for different designs to asses the rollback and nominal stress condition on the cam surface.

INTRODUCTION

Clinically retention of Posterior Cruciate Ligament has show to be more advantage than PCL sacrificed TKA. PCL retention will prevent posterior subluxation of the tibia and will improve the femoral rollback. Femoral rollback is said to improve knee extension strength and increase the range of motion in deep flexion. Furthermore, femoral rollback increases the quadriceps lever arm.

The posterior stabilizer replaces the function of PCL in PCL sacrificed tibial component. The literature on PS TKA suggests that longevity of fixation is excellent and the rate of femoral and tibial loosening was 2% and 3%, respectively in a 9 to 12 years follow-up study. Dislocation and extra bone resection make this stabilizer option less than ideal.

The rollback is induced when the femoral cam articulate with the tibial post. Due to the cam-spine mechanism posterior translation of the femoral component occur which results in reduction of posterior translation of the tibial component relative to femoral component. So the posterior displacement of the femoral component increases the moment arm of the quadriceps and allows further flexion of the knee up to 120 degree.

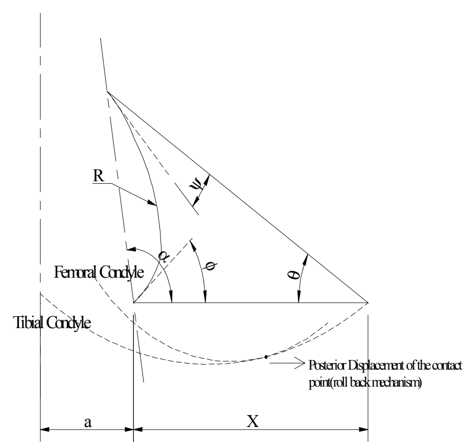

Figure 1 Schematic design of posterior stabilizer mechanism

Design parameter	Φ degrees	Ψ degrees	X cm	a cm	R cm
θ=15	65	22	2.83	1.6	0.55
θ=20	63	15	2.98	0.95	0.55
θ=25	60	19	2.87	1.06	0.5
θ=30	**65**	**13**	**2.73**	**1.21**	**0.45**
θ=35	62	16	2.65	1.43	0.45

Table 1 Variation of posterior stabilizer design parameter and their relationship

METHODS

In order to study the influence of the geometric parameters of the tibial post that influence the femoral rollback mechanism different designs of the PS tibial component are considered with varying dimensions as listed in table-1. No changes are made in the geometry of the femoral cam. All the dimensions of the stabilizing post are derived from the independent parameters (X, h, θ, ψ, and φ) as shown in Figure 1. Default design is the one with θ=30 in the table 1.

The solid model of the tibial and femoral component were created and assembled for high flexion angle (when the tibial spine makes contact with femoral cam) in pro-E and imported to ANSYS. Quasi-Static finite element model of the TKA with different design of the PS were developed using SOLID92 tetrahedral elements as shown in figure 2. Non-linear contact model is developed to study the rollback mechanism and distribution of pressure on the interfaces of the TKA. Pressure values from experimental results are applied on the femoral component of the TKA.

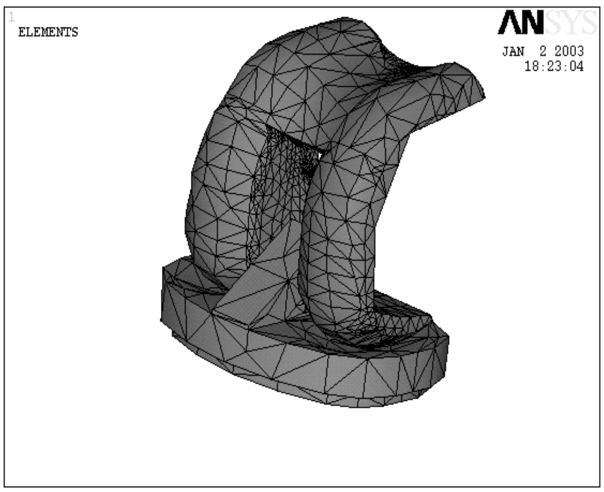

Figure 2 FEM model of the TKA roll back.

RESULTS

The distribution of pressure on the tibial spine is compared for different designs and also the posterior displacement of the contact points with the original design (θ=30). At high flexion angle the pressure distribution on the articulating surface is not significant (quadriceps and ligaments takes the load) it was not used as a design parameter. An optimized design is the one which have considerable posterior displacement to avoid posterior subluxation of the tibia and stress distribution on the surface of the tibial post not exceeding the yield stress of the polyethylene.

Different Design/Design Parameter	Pressure Distribution on the tibial Spine(KPa)	Maximum Pressure Distribution on the tibial insert(KPa)	Posterior Displacement of the femoral Component (cm)
θ=15	156	285	0.1507
θ=20	246	447	0.233
θ=25	241	386	0.134
θ=30	183	345	0.146
θ=35	169	468	0.2148

Table 2 FEM results at the start of rollback mechanism

DISCUSSION

Comparing the results of the pressure distribution on the cam curvature indicates that there is indeed a significant influence of the design parameters on the rollback mechanism. From the results we see that (θ=35°) parameters in the slope design has a better posterior displacement and reduced pressure distribution when compared to the other designs under consideration. Looking at the geometric parameter φ for this design, φ=62° is the smallest when compared with others. The smaller the angle the smoother will be the path traces by the contact point on the tibial post during the start of the rollback.

When θ is decreased there is an increase in the posterior displacement but the pressure distribution on the tibial spine increases and the peak pressure at some points has a very high value which may lead to early degeneration of the polyethylene

The model presented is kept geometric significant but the consideration of the ligaments to predict the actual displacement taking place during the rollback mechanism is left out. Hence the focus is the understanding of the kinematics of the different design to find a better set of design parameter and the study can be extended to a detailed analysis with ligaments and muscles with this parameters.

REFERENCE

1. Aram L, Amirouche F 2001: Characterization of contact Pressure in Total Knee Arthoplasty as a function of component position and ligament Balance. Proc Instn Mech Engrs.
2. Amirouche F., Gonzalez M., Aram L., Giachetti R., Mahr, C.: A Contact Pressure Based Prosthetic Fitting Device For a Total Knee Arthroplasty (TKA). The Proceedings of the Engineering of Sport – 3rd International Conference and Exhibition. 2000
3. Shuichi Matsuda, 1997, Knee kinematics of posterior cruciate ligament sacrificed total knee Arthroplasty, Clin Othro Rel Research 341, pp 257-266.
4. Mahoney M, Philip C 1994. : Posterior Cruciate function following total knee arthroplasty, J Arthroplasty Vol 9 No 6.
5. Shinichi, kadoya, yoshinor 1998.: Anteroposterior and Rotational Movement of femur During Knee Flexion. Knee.
6. Mottershead JE, Edwards PD:Finite element analysis of a total knee replacement by using gauss point contact constraints. Proc Instn Mech Engrs Vol 210.
7. McGloughlin T M, Monaghan J M ,1997 : Contact stress analysis of the tibial component of prosthetic knee implants. Proc Instn Mech Engrs Vol 211 part H.
8. Darryl D, Lima D 2001 :Polyethylene Contact Stresses Articular Congruity, and knee Alignment. Clin Ortho & Rel Research. No 392 pp 232-238.
9. Markus A, Wimmer 1997 : Tractive forces during rolling motion of the knee implications for wear in total knee replacement. J Biomech Vol 30 No 2 pp131-137.
10. Markus S, Graeme A, 1996 : Joint load consideration in total knee replacment, J Bone Joint Surg 79-B:109-13.