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TOTAL CONDYLAR PROSTHESIS PLACEMENT IN KNEE ARTHROPLASTY

Biomechanic Analysis of Human Knee Preparations

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Knee replacement using the Total Condylar Prosthesis was carried out on six large cadaveric knees. Tibiofemoral articulation was studied radiographically with the tibial component placed anteriorly as well as posteriorly on the tibial plateau. It is concluded that, in this model, when using the Total Condylar Prosthesis for big-sized knees, a tall, posteriorly placed tibial component gave the best placement of the femoral component and the most central tibio-femoral articulation, entailing optimal distribution of the load on the trabecular bone beneath the tibial component.

Key words: arthroplasty; joint prosthesis; knee joint, biomechanics

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Condylar replacement types of knee prosthesis can to a great extent reproduce the motion of the intact joint, if the shapes of the implanted components are closely anatomical and are matched in size to the joint (Walker et al. 1972). A careful surgical technique, with exact resection of bone, ligament balancing, and centralizing of the prosthesis are required for optimal stability and load transmission to the tibia, and thereby for a good operative result (Insall et al. 1976, Walker et al. 1976, Ducheyne et al. 1978, Kaufer et al. 1978, Walker 1978, Waugh 1978, Laskin 1979).

In arthroplasty performed with the Total Condylar Prosthesis (Insall et al. 1976), stability in the unloaded and lightly loaded knee is secured mainly by the ligaments, while at a greater load this function is taken over by the components (Walker & Hsieh 1977). The Prosthesis is made in various sizes, but unlike the width the anteroposterior extent of the components varies by only a few mm. In populations, such as the Scandinavian ones, in which many patients have a heavy bone construction, there will quite often be cases in which the discrepancy between the dimensions of the components and of the joint may pose problems in prosthetic function.

Using large cadaveric knees, we studied the relation between different placements of the prosthetic components, articulation conditions in the tibio-femoral joint, and the femoral insertion of the medial collateral ligament. Our aim was the optimal placement of the Total Condylar Prosthesis in big-sized knees.

MATERIAL AND METHOD

The study comprised six large knee preparations which had been removed in the autopsy room a short time after death and kept at –18°C until use. None of the

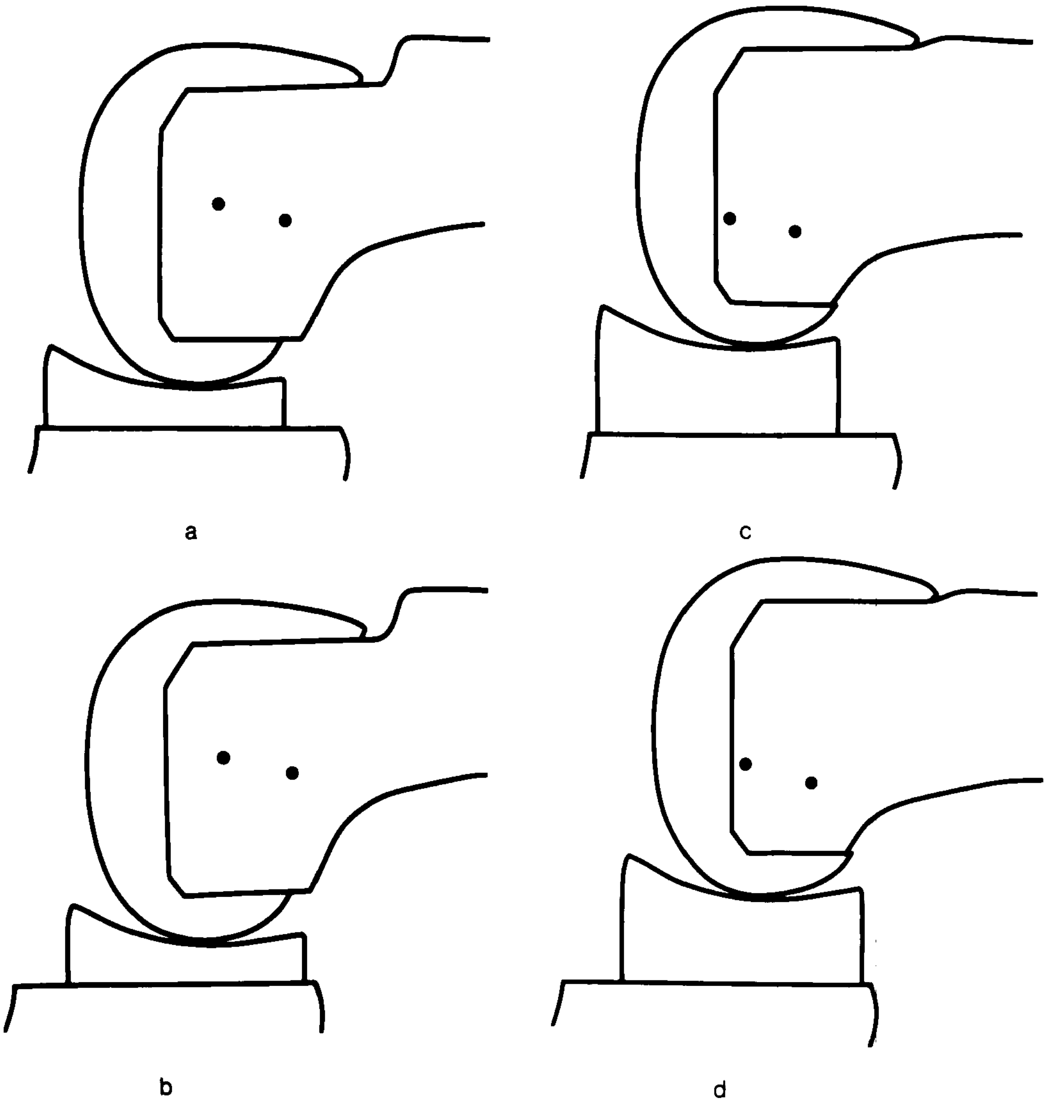

Figure 1. a: 7.5 mm tibial component placed anteriorly.
b: 7.5 mm tibial component placed posteriorly.
c: 15 mm tibial component placed anteriorly.
d: 15 mm tibial component placed posteriorly.

preparations had major pathological changes, and in all of them the capsular apparatus was preserved. The frontal diameter of the femoral condyles was 88–96 mm, the anteroposterior diameter of the medial femoral epicondyle 70–75 mm, and the anteroposterior diameter of the tibial plateau in the midline 48–62 mm.

Into all preparations, a 65 mm Total Condylar Prosthesis of the Insall-Burstein type in which the anteroposterior extent of the tibial component is 41 mm was implanted without cement. For three preparations, a 7.5 mm and for the other three a 15 mm tall tibial component was used. Each knee was studied with the tibial component placed anteriorly as well as posteriorly on the tibial plateau. The change from the anterior to the posterior position in the six knees amounted to 6–10 mm, mean 8.3 mm.

When arthroplasty is carried out in a big-sized knee using a constant, minimal tibial resection, the use of a 7.5 mm tibial component entails a major anterior and a minor distal and posterior femoral resection at a great distance from the femoral insertion of the medial collateral ligament (Figure 1a–b). A 15 mm component entails a major distal and posterior femoral resection close to the ligament insertion; thereby, the femoral component is placed closer to the anterior aspect of the femur (Figure 1c–d).

The preparation was fixed, by the femur, in a stand permitting three-dimensional adjustment. The joint was opened by a parapatellar incision, and the femoral insertions of the anterior and posterior parallel fibres of the superficial medial collateral ligament were marked by metal pins. The joint was closed by interrupted sutures in the capsule. Under fluoroscopy the preparation was adjusted so that the contours of the femoral epicondyles were superimposed, and a series of films were exposed with the knee flexed 0, 30, 45, 60, 90, and 120 degrees. Thereafter, the arthroplasty was done, placing the tibial component anteriorly. After the joint had been closed, a new series of films was exposed. A third series was exposed with the tibial component placed posteriorly on the tibial plateau.

The movement of the ligament insertion in relation to the tibia – and to the tibial component – was determined for each preparation before and after the insertion of the prosthesis by transferring the marks from the films to a sheet of thin paper.

The distance from the tibio-femoral contact to the anterior edge of the tibial component at 30–90° flexion was calculated for each film, the distance being corrected, using the anteroposterior extent of the tibial component as reference.

The influence of the placement of the tibial component on the distribution of stress in the underlying bone was investigated on a load model (Wolf 1976). A plexiglass model of the tibia, tibial component and femoral component was constructed on the basis of X-ray films of a preparation with an inserted prosthesis. The femoral component was loaded so that the load was transferred to the middle and posterior third of the tibial component, respectively. Polarized light was transmitted through the model which was photographed through a polarization filter.

The results of the measurements are stated as mean values ± SEM.

RESULTS

With 7.5 mm as well as 15 mm tibial components, it was found that in all knees moving the component from the anterior to the posterior position resulted, at the same degree of flexion, in an anterior displacement of the tibio-femoral contact.

During 30–90° flexion, the contact in all knees moved anteriorly with both placements (Figures 2 and 3). During full extension, the femoral component was in contact with the entire tibial component, and in three cases 120° flexion gave contact between the femur and the posterior edge of the tibial component. These degrees of flexion are therefore not included in Figures 2 and 3.

When the tibial component was placed anteriorly, articulation took place, regardless of the height of the component, on the posterior third, most posteriorly with 7.5 mm components. When the component was placed posteriorly, the entire

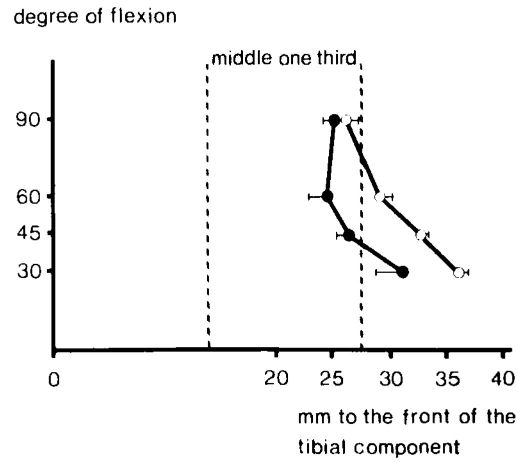

Figure 2. Mean distance from the tibio-femoral contact on the tibial component to its anterior edge in the three knees in which a 7.5 mm component was placed anteriorly (○——○) and posteriorly (●——●).

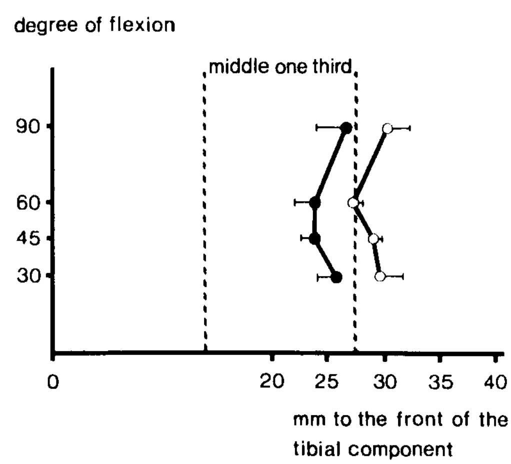

Figure 3. Mean distance from the tibio-femoral contact on the tibial component to its anterior edge in the three knees in which a 15 mm component was placed anteriorly (○——○) and posteriorly (●——●).

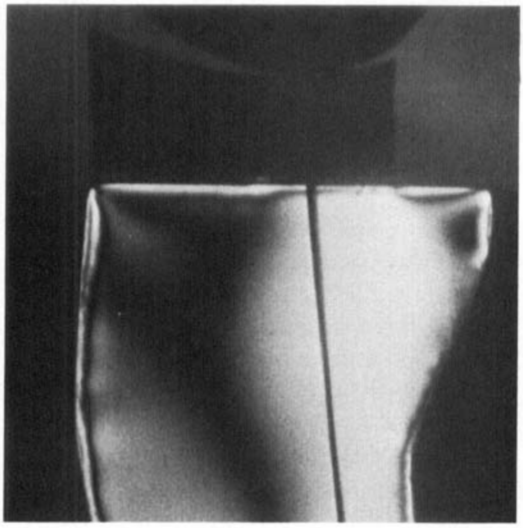

Figure 4. The tibial component is loaded on its posterior third. The transmission of weight to the tibia is concentrated in an area corresponding to about 3/8 of the extent of the tibial component.

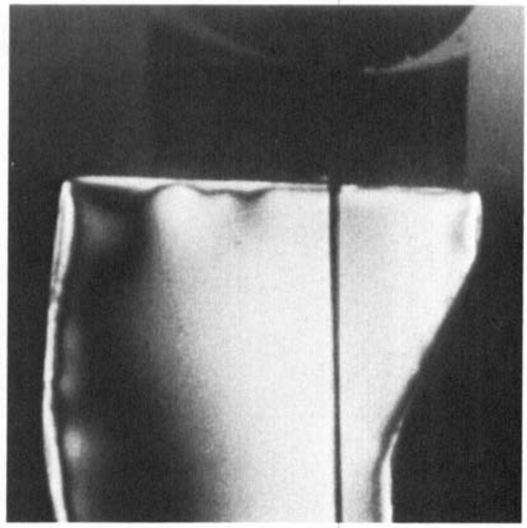

Figure 5. The tibial component is loaded on its middle third. The weight is transmitted to the tibia in an area corresponding to the entire extent of the tibial component.

articulation took place on the middle third when using 15 mm components and for 60–90° flexion when using 7.5 mm components.

In the load model, the weight was transmitted to the tibia through the posterior approximately 3/8 of the tibial component when the load was on its posterior part, while the load was evenly distributed on the entire area beneath the compo-

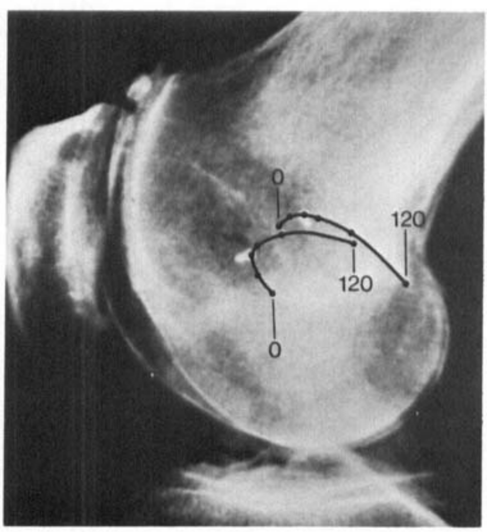

Figure 6. The recorded movements of the anterior and posterior ligament insertions in relation to the tibia prior to the replacement.

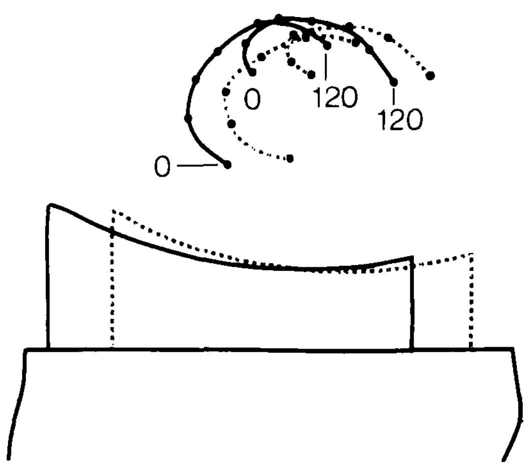

Figure 7. Movements of the ligament insertions in relation to the tibial component in the same knee as in Figure 6 after the insertion of a 7.5 mm tibial component. The configuration of the recorded movements is as in the intact knee, both with anterior (——) and posterior (----) placement of the component.

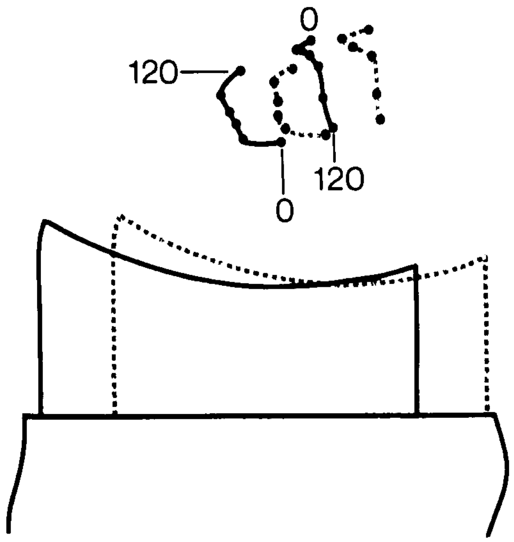

Figure 8. Movements of the ligament insertions in a knee in which the anthroplasty was done with a 15 mm component. The excursions are considerably smaller than in Figure 7.

nent when it was loaded centrally (Figures 4 and 5).

The configuration of the recorded movement of the ligament insertion altered very little in relation to the intact knee when the arthroplasty was performed with 7.5 mm components, while the excursion was considerably smaller with 15 mm components (Figures 6–8).

DISCUSSION

From Seedhom et al.'s (1972) investigation of the dimensional relations of knee joints, it is apparent that in 6 per cent of the population studied (20 per cent of the males), the transverse diameter of the femoral condyles exceeded 90 mm, and the anteroposterior diameter of the medial femoral epicondyle exceeded 70 mm. The anteroposterior diameter of the tibia was not measured in that study, but we found that in knees of the dimensions given above the size of the tibial plateau allowed quite essential changes in the placement of the tibial component.

Cutting the cruciate ligaments when implanting non-hinged prostheses affords a risk of posterior subluxation of the femur, whereas anterior subluxation could not be induced experimentally with the Total Condylar Prosthesis (Freeman et al. 1977, Markolf et al. 1979). The difference in anteroposterior stability is due partly to the design of the tibial component, the elevation posteriorly being less than anteriorly; therefore, the stabilizing uphill movement (Freeman et al. 1977) is less marked. The use of 15 mm components resulted in a shorter distance between the ligament insertion and the joint surfaces which, in combination with the more central articulation, must make for better anteroposterior stability.

Like Wirth & Küswetter (1980), we found the connecting line between the anterior and posterior ligament insertion to be almost parallel with the long axis of the femur, while in Bartel et al.'s (1977) study it was at right angles to the femur. Accordingly, the configuration of the movement recorded in the intact knee in their study and in ours is different.

The design of the prosthesis endeavours to reproduce the motion of the intact knee. Judging by the configuration of the recorded movement of the ligament insertion before and after arthroplasty, this was achieved with the 7.5 mm tibial components. Owing to the discrepancy between the anteroposterior extent of the component and of the tibial plateau, however, articulation took place marginally on the posterior part of the component when it was placed anteriorly. It was possible to compensate for this partially by moving the component posteriorly, but 7.5 mm components also entail essential weakening of the femur and of quadriceps function owing to the marked anterior resection of the femur.

In addition to a better placement of the femoral prosthesis, the use of 15 mm components entailed a more central articulation, which takes place, in the flexion degrees recorded, exclusively on the middle third of the posteriorly placed components.

A number of investigations have demonstrated that the placement of load on the tibial component is decisive for its fixation in the long term (Ducheyne et al. 1978, Walker 1978). Thus, Walker et al. (1976) found experimentally that loads outside the middle third of the tibial component entailed tilting of its unloaded part, resulting in loosening between cement and bone.

In unloaded knee preparations when using the Total Condylar Prosthesis for big-sized knees, a tall, posteriorly placed tibial component will afford the best placement of the femoral component and a more central tibio-femoral articulation, resulting in optimal load transmission to the trabecular bone beneath the tibial component.

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