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Posterior cruciate ligament (PCL) reconstruction – an in vitro study of isometry

Part II. Tests using an experimental PCL graft model

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Abstract. Isometric positioning of the posterior cruciate ligament (PCL) graft is important for successful reconstruction of the PCL-deficient knee. This study documents the relationship between graft placement and changes in intra-articular graft length during a passive range of motion of the knee. In eight cadaveric knees the PCL was identified and cut. The specimens were mounted in a stabilising rig. PCL reconstruction was performed using a 9-mm-thick synthetic cord passed through tunnels 10 mm in diameter. Three different femoral graft placement sites were evaluated: (1) in four specimens the tunnel was located around the femoral isometric point, (2) in two specimens the tunnel was positioned over the guide wire 5 mm anterior to the femoral isometric point, (3) in two specimens the tunnel was positioned over the guide wire 5 mm posterior to the isometric femoral point. In all knees only one tibial tunnel was created around the isometric tibial point. The location of the isometric points is described in part I of this study. The proximal end of the cord was fixed to the lateral aspect of the femur. Distally, the cord was attached to a measuring unit. The knees were flexed from 0° to 110°, and the changes in the graft distance between the femoral attachment sites were measured in 10° steps. Over the entire range of motion measured, the femoral tunnels positioned around the isometric point produced femorotibial distance changes of within 2 mm. The anteriorly and posteriorly placed tunnels produced considerable changes in femorotibial distance with knee flexion, e.g. about 8 mm at 110° of flexion.

Key words: Posterior cruciate ligament – Isometry – Method for correct placement

Introduction

According to Clancy et al. [1], the substitution of the posterior cruciate ligament (PCL) with a B-PT-B graft in the tunnel-tunnel technique is superior to other reconstructive procedures. In order to ensure that the transplant is protected against mechanical overstress during the revitalisation and remodelling phase, an additional augmentation by synthetic ligament material is recommended [4, 6]. It is very important for the isometry of the transplant, which itself is the key factor for regaining stability and physiological joint kinematis, that the osseous passage tunnels be placed correctly. These tunnels have a diameter of 10–13 mm.

In Part I of this study, six measuring points in and around the femoral and tibial insertion of the PCL were defined on knee specimens, and the femorotibial changes in distance between the individual measuring points were recorded from 0° of extension to 110° of flexion by using a string linkage model. The femoral and tibial isometric points were established from the results of the data. In addition, we described a simple method to define the femoral isometric zone. It was demonstrated that deviations of the femoral isometric point lead to excessive femorotibial changes in distance during increasing knee flexion. Deviations of the tibial isometric point lead only minimally to larger femorotibial changes in distance, except in the "over the back" position. Similar results have been published by Friederich and O'Brien [2], Grood et al. [5] and Ogata and McCarthy [7].

We wanted to answer the question of how the results of the string linkage model could be transferred to a PCL substitution with a voluminous transplant. Furthermore, we wanted to explore how the isometry of the transplant is influenced by larger bone tunnels. Therefore, we proceeded to make isometric measurements with a non-elastic, 9-mm-sized, plastic string PCL graft model, using bone tunnels of 10 mm in diameter.

Materials and methods

The investigations were made with a total of eight cadaver knee specimens. We used the six knee specimens from part I and two further ones, removed from male cadavers (55 and 61 years old). The framework and measuring apparatus in part I were applied. As a transplant graft model for PCL substitution, a 9-mm, non-elastic, plastic string was used. In order to make the passages for the graft

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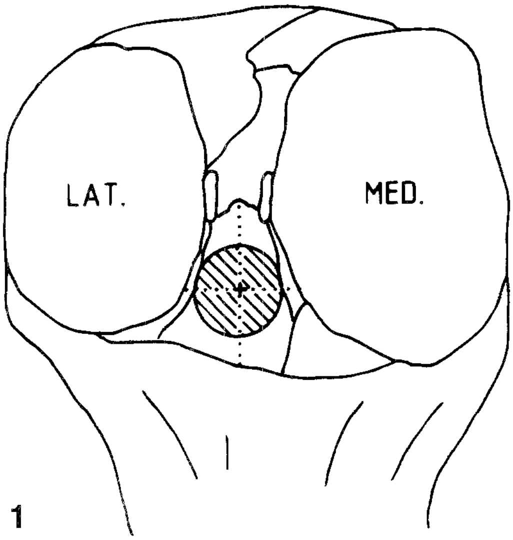

Fig. 1. Localisation of the tibial bone tunnel around the isometric point in the centre of the posterior intercondylar area

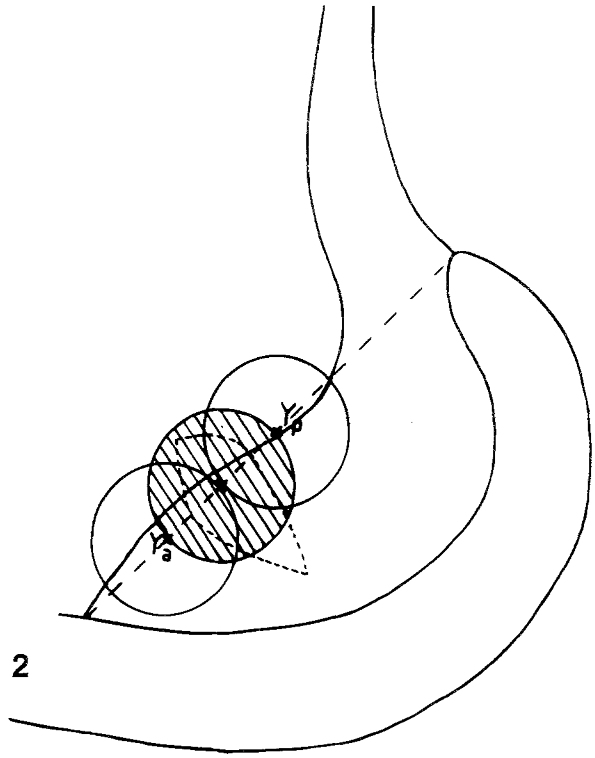

Fig. 2. Localisation of the femoral bone tunnels. The *hatched* bone tunnel Yi is located around the femoral isometric point. The centre of bone tunnel Ya is located 5 mm anterior to the isometric point. The center of bone tunnel Yp is placed 5 mm posterior to the isometric point. The *dotted line* encloses the 2-mm isometric zone

model through the femur and the tibia, bone tunnels 10 mm in diameter were drilled. Only one tibial bone tunnel was drilled because the whole tibial area intercondylaris is usable as an appropriate isometric zone. The 10-mm bone tunnel was drilled around a Kirschner wire which was placed on the tibial isometric point (Fig. 1).

Three separate bone tunnels in the femur were examined. In four specimens the bone tunnels were drilled around a K-wire placed at the femoral isometric point, described as Y1. We defined the femoral isometric point by a special method. The length of the borderline between the roof of the intercondylar notch and the medial femoral condyle was measured and divided by three. The exact femoral isometric area is localised one-third of this distance away from the anterior cartilage-bone border at the inner wall of the medial femoral condyle.

In two specimens the K-wire was placed 5 mm anterior to the isometric point. In two other specimens the K-wire was placed 5 mm posterior to the isometric point. The anterior bone tunnel was called Ya, and the posterior bone tunnel was called Yp (Fig. 2).

The measurements of the femorotibial changes of distance were made in the same way as in part I, namely the plastic string excursions were registered in 10° steps, over range of motion from 0° of extension to 110° of flexion. The plastic string was placed under a pre-tension of 10 N. Before each measurement the knee joints were flexed several times, and the measuring apparatus was adjusted to 0 by flexing the kneee 10°. Each separate measurement was made three times and an average value calculated.

Results

The femorotibial changes of distance of the four specimens in which the bone tunnels were drilled around the femoral isometric point are shown in Fig. 3. Overall, with increasing flexion there was an increase of the femorotibial change of distance, which, however, was less than 2 mm throughout the whole measured range of motion. The 1-mm mark was surpassed only in a range of between 60° and 90° of flexion. The diverging course of the curves

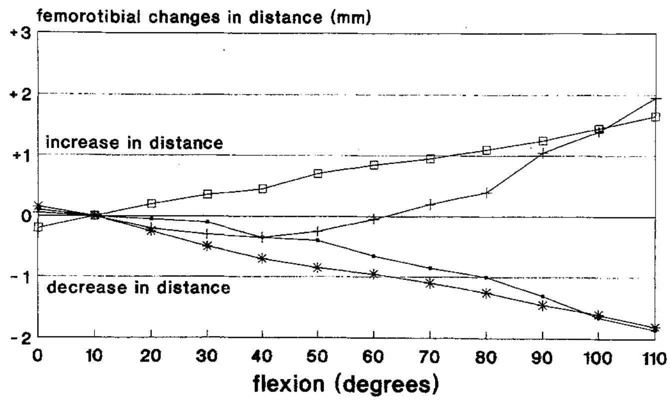

Fig. 3. Femorotibial changes in distance for the isometrically drilled bone tunnels Yi, depending on knee flexion. The femorotibial changes in distance are less than 2 mm throughout the whole range of motion. —•— Knee 1, —+— knee 2, —*— knee 3, —□— knee 4

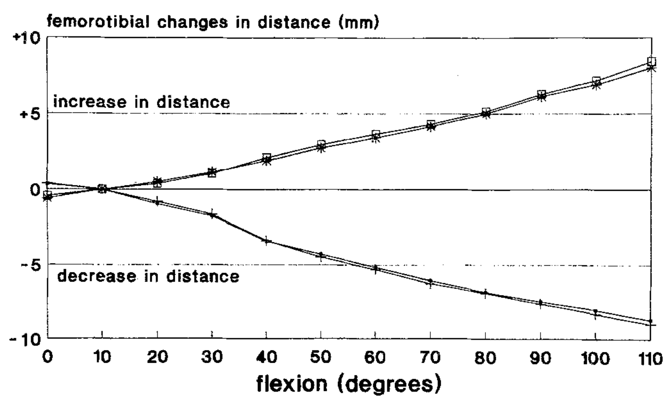

Fig. 4. Femorotibial changes in distance for the bone tunnels which were drilled anterior (Ya) and posterior (Yp) to the isometric point, in relation to knee flexion. —•— Knee 5, —+— knee 6, —*— knee 7, —□— knee 8

shown in Fig. 3 can be explained in two ways. There may have been deviations in defining the isometric point or slight errors in the angle drilling around the K-wires.

In Fig. 4 it can be observed that the bone tunnels which are placed anterior and posterior to the femoral isometric point lead to progressive femorotibial changes in distance. In 110° of flexion, an average of 8 mm increase in the femorotibial distance was observed for the anterior bone tunnel Ya. The posterior bone tunnel Yp showed a decrease of distance of nearly 9 mm. The 1-mm mark was already achieved with 25° knee flexion, while the 5-mm mark was exceeded between 60° and 80° of flexion.

Discussion

We are aware that it is not possible to reconstructed the exact anatomy of the PCL. Therefore, the key goal of PCL substitution is to regain the ligament's special. Using an autogenous transplant, one important condition for achieving this goal is to place the ligament substitute in an isometric position. Isometry means that there are only minute changes of distance between the femoral and tibial anchor areas during the entire range of motion. This guarantees that the transplant maintains constant length and tension during knee movements. Only in this way is the substitute ligament protected from stretching and disruption in the early postoperative period and can take over the controlling function of the natural ligament for joint kinematics and regenerate itself into a biomechanically effective stabiliser.

Ideal isometry (0 mm isometry) cannot be achieved with voluminous transplants such as are necessary for PCL substitution. Nevertheless, the femorotibial changes in distance should not exceed 2 mm during the whole radius of motion. If this 2 mm isometry is achieved, the small changes of distance between the anchor areas can be compensated by the elasticity of the collagenous tissue. Also, the elastic reserve of the augmentation ligament is so great that the femorotibial changes of distance up to 2 mm can be compensated without damage to the synthetic material.

Part I of our study showed that with the exception of the "over the back" position, the whole tibial insertion of the PCL may be utilised as an appropriate isometric zone. Because of this fact, we made only one tibial bone tunnel, which was placed around the tibial isometric point in the centre of the posterior intercondylar area.

In the femur, three tunnels were drilled. The bone tunnel which was placed around the femoral isometric point led to femorotibial changes of distance smaller than 2 mm during a range of motion from 0° of extension to 110° of flexion. This shows that a 2-mm isometry can be achieved by using voluminous substitute PCL transplants if the bone tunnels were well defined and correctly located.

In our investigations we were not able to achieve the isometric value of 0.4 mm, as given by Friederich and O'Brien [2], who used patella ligament transplants and bone tunnels with a diameter of 12 mm.

We noticed excessive femorotibial distance changes during knee flexion for the bone tunnels which were placed away from the femoral isometric point in the anterior or posterior directions. For the bone tunnel placed anterior to the femoral isometric point, there was an increase of nearly 8 mm in 110° knee flexion. A 9-mm decrease was measured for the bone tunnel placed posterior to the femoral isometric point. Together with the results presented in part I, the data underscore the necessity of placing the femoral bone tunnel very precisely when doing a PCL substitution, so that the 2 mm isometry is not exceeded.

The most appropriate femoral isometric zone is not identical with the anatomic insertion of the PCL.This was already described by Grood et al. [5] as well as by Friederich and O'Brien [2]. This zone is located eccentrically from the insertion area at its posterosuperior margin [3, 7]. The distance measured along the borderline between the inner wall of the medial femur condyle and the sulcus roof, beginning at the anterior cartilage-bone border up to the isometric point, assists in the correct placing of the target wire. This line amounts to an average of 11 mm, with a standard deviation of ± 2 mm, as described in part I. A nearly identical value was found by Grood et al. [5].

We used the reproducible method described in part I to define the exact femoral isometric area. This method is very practical and can easily be applied in the operative situation. In all cases we exactly localised the femoral isometric area. We believe that this method will be very helpful in obtaining good isometric results without intraoperative isometry measurements.

The tibial passage tunnel is appropriately placed in the centre of the posterior intercondylar area. This region is easily reachable by means of an anterior arthrotomy, and the K-wire can be correctly placed under direct view or under palpatory control. Also, the passage of the transplant is not so difficult, and an additional incision is not necessary. The transplant passage through a bone tunnel in the "over the back" position is not only technically more difficult, but also compromises the isometric situation.

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