The Transpatellar Approach for the Knee in the Laboratory

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Received 15 May 2008; accepted 10 July 2008
Published online 8 October 2008 in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/jor.20755

ABSTRACT: This paper describes a longitudinal patellar-splitting approach to the knee that includes provision for accurate reconstruction. Our in vitro experiments showed that patellofemoral kinematics and length-change patterns of specific bands of the peripatellar retinaculum were not changed significantly by opening and closing the knee via the transpatellar approach. This surgical approach will be useful for in vitro experiments on the knee, when effects due to alterations of internal structures such as cruciate ligament reconstructions or joint replacement are to be studied, avoiding confounding effects caused by changes to the retinaculum. © 2008 Orthopaedic Research Society. Published by Wiley Periodicals, Inc. J Orthop Res 27:330–334, 2009

Keywords: knee; surgical approach; retinaculum; kinematics

In the past, the patellar splitting approach was considered a reasonable option for gaining wide exposure of the knee. Insall credited Sir Robert Jones for the patellar splitting approach.1 In 1971, Insall modified this incision to retain inherent advantages of excellent exposure, but eliminate the disadvantages of splitting the patella.2 His incision elevated the soft tissue underlying the patella, but distally still split the patellar tendon. Splitting the patella was used in case reports for osteochondritis dessicans2 and exploration and meniscectomy.3 Henderson4 utilized the incision to obtain good exposure for difficult cases in removal of loose bodies.5 In pediatric physeal fractures of the distal femur, he recognized the importance of accurate reduction of the articular surface, and therefore did not hesitate to perform a wide exposure by splitting the patella.6 However, around the same time, the medial parapatellar approach was described to gain adequate exposure of the knee without splitting the patella.7

We are involved in biomechanical work to characterize changes in kinematics and ligament length as a result of surgical intervention and prosthesis geometry. So as not to change the properties of the extensor retinaculum, we explored the utility of the patellar splitting approach for laboratory use. Our aim here was to verify that significant changes in kinematics and length changes of the attachments of the extensor retinaculum (the lateral retinaculum and the medial and lateral patellofemoral ligament) did not occur with a patellar splitting approach. Our hypothesis was that a longitudinal patella-splitting approach allows adequate access to the knee but does not impact patellofemoral kinematics or the extensor retinaculum length.

MATERIALS AND METHODS
Specimen Preparation

Nine fresh-frozen cadaveric knees (mean age = 64 years, SD = 16 years) were obtained from the International Institute for the Advancement of Medicine (Jessup, PA). The institute undertook screening and consent for their use for research. Ethical permission for the study was obtained from the Riverside Research Ethics Committee. The knees were stored at −20 °C and thawed a day prior to experimentation.

The skin and subcutaneous tissue were removed. The deep fascia, retinaculum, and iliobibial band (ITB) were preserved. The femur and tibia were cut approximately 20 and 15 cm above and below the knee, respectively. The fibular head was transfixied to the tibia by two bone screws to maintain its anatomical position, and then the distal part was excised. Using PMMA and after preparation of the medullary cavity, an intramedullary sleeve and a rod were cemented into the femur and tibia, respectively. The sleeve and the rod were aligned to the anatomical axes by use of rubber spacers and an outrigger alignment rod. The quadriceps was separated into six components: rectus femoris (RF), vastus intermedius (VI), vastus lateralis longus (VLL), vastus lateralis obliquus (VLO), vastus medialis longus (VML), and vastus medialis obliquus (VMO).

The knee was mounted anterior upward in a rig by locating the cemented femoral sleeve onto a rod on a femoral mounting device; this allowed rotation of the femur to be adjusted and fixed with the most posterior parts of the femoral condyles horizontal in a distal–proximal view. The quadriceps components and the ITB were each loaded with hanging weights using cables and pulleys with a total of 175 N8 and 30 N8,10 respectively. This was done according to the directions and physiological cross-sectional areas (PCSAs) of the muscles11 relative to the femoral axis: VLL, 14° lateral and 0° anterior; VLO, 35° lateral and 33° posterior; VML, 15° medial and 0° anterior; VMO, 47° medial and 44° posterior; and RF + VI, 0° lateral and 0° anterior. The quadriceps tension distribution was: RF + VI, 35%; VLL, 33%; VLO, 9%; VML, 14%; and VMO, 9%. The direction of pull of the ITB was 0° lateral and 6° posterior.9

Tracking

The kinematics of the patellofemoral joint were measured dynamically using a Polaris optical system (Northern Digital Incorporated, Waterloo, Canada) with active optical trackers (Fig. 1). The knee was moved into two cycles of flexion-extension, against the extending moment of the quadriceps tension using a rod held transversely against the anterior surface of the tibial intramedullary rod. The femoral coordinate system was centered on the anatomical axis and
adduction, and z was internal.

From medial and lateral points of the tibial plateau. The raw system was based on the intramedullary axis and the most the transverse and coronal planes. The tibial coordinate system was constructed with its origin at the center of the midpoint of the patellar median ridge. The patellar coordinate system was based on the intramedullary axis and the most posterior points of the femoral condyles. The center of the patella was defined as 10 mm deep to the anterior surface and offset medially and in the proximal–distal direction to overlay the proximal–distal midpoint of the patellar median ridge. The patellar coordinate system was constructed with its origin at the center of the patella and aligned to the medial, lateral, and distal points in the transverse and coronal planes. The tibial coordinate system was based on the intramedullary axis and the most medial and lateral points of the tibial plateau. The raw kinematic data were processed with Visual3D (C-Motion Inc., Germantown, MD). The points that defined the local coordinate system of each bone were used to create bone segments in the software, the motions of which were linked to the motion of their respective trackers.

During the motion cycle, the software calculated the transformations required between the femoral segment and the patella or the tibia by a series of rotations and translations in three orthogonal planes. The default Cardan sequence was x, y, and z, where x was flexion-extension, y was abduction-adduction, and z was internal–external rotation. This sequence is equivalent to the joint coordinate system for the knee. From these data, patellar kinematics in relation to the femur and the knee (tibiofemoral) flexion angle were determined. Lateral patellar tilt was defined as a rotation about the longitudinal patellar axis; more positive values indicated that the lateral patella moved further posterior. Patellar lateral rotation was in the patella's coronal plane and was analogous to abduction; an increase in lateral rotation meant that the distal patella moved laterally relative to its center. Lateral translation was defined as translation along an axis perpendicular to the anatomical axis of the femur and parallel to the plane that passed through the most posterior parts of the femoral condyles, that was zeroed at 0° tibiofemoral flexion.

**Ligament Length Change**

Length changes between the attachments of the extensor retinaculum were measured using sutures attached to LVDTs (Solatron, Metrology, UK; Fig. 1). For each of the medial patellofemoral ligament (MPFL) and the lateral patellofemoral ligament (thickening of the lateral capsule), a suture was passed from a stationary transducer through a screw eye secured to the femoral attachment of the ligament, then passed along the structure, terminating at the patellar attachment. The most distinct component of the lateral retinaculum was the fibers that passed from the ITB to the lateral patella. Therefore, for the lateral retinaculum, two transducers were required. In one, the suture went through the screw eye in the ITB and terminated at the patella; the other transducer was attached to just the ITB screw eye. Subtraction of the reading of one transducer from the other gave the ligament length change for the lateral retinaculum. The transducer readings were zeroed with the knee in extension.

**Patellar Split (Transpatellar) Surgical Technique**

Before splitting the patella, two straight 1.3-mm wires were passed across the medial–lateral width of the patella, proximal, and distal. These were over drilled to 2.7 mm diameter using a cannulated drill bit. This predrilling allowed for accurate fixation with screws after the patellar split. A fine saw was used to cut the patella lengthwise in a proximal–distal direction about 10 mm lateral to the midline; the larger medial fragment allowed the mounting of the optical tracker to be undisturbed (Fig. 2). However, also, too lateral a cut was avoided so that when extended distally it would pass into the substance of the patellar tendon. The cut was performed with the knee flexed to 90° and with tension applied to the quadriceps to stabilize the patella. When sufficiently deep, the last remaining bone was cracked open by wedging an osteotome in the gap. The split was completed by cutting the articular surface with a scalpel. This cut was extended distally and proximally in the line of the fibers of the patellar and quadriceps tendon, respectively. The patellar fat pad was partially excised to allow for visualization.

After inspection of the joint, the two cut surfaces of the patella were approximated and fixed with two 4.0-mm

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**Figure 1.** A right knee is placed in the jig. Optical trackers are secured to the femur (F), patella (P), and tibia (T). LVDTs (L) measure length changes between the attachment sites of the extensor retinaculum.

**Figure 2.** The patellar splitting approach. (a) A saw is used, and an osteotome completes the split from proximal to distal. (b) Good visualization of the knee is obtained. The predrilled holes can be seen on the lateral fragment and the mounting for the tracker can be seen on the medial fragment. (c) After closure with two cannulated 4.0-mm cancellous screws.
cannulated semithreaded cancellous screws. The saw blade was placed in the split before final tightening of the screws to allow for the bone lost when cutting. The split in the patellar tendon was left alone as it did not separate when the knee was loaded and flexed. The split in the quadriceps tendon was opposed with a continuous suture that could be loosened and tightened when joint access was required.

**Experiment 1**
The ligament length change pattern for the MPFL was determined in one knee. The knee was flexed and extended twice and the transducer recordings were made. The tracking system was used to measure flexion angles. The results were averaged for the two cycles. Two more runs were made about 30 min apart. Then, the patella was split and fixed as described, and the MPFL length change was measured during the flexion cycle. The screws were removed, the knee reopened, and then the screws were replaced to close the patellar split. This was done six times in total. Last, a standard medial parapatellar incision was made, taking care not to cut the suture that passed along the MPFL. Transducer readings were taken after the repeated closure of the patellar split and the medial parapatellar approach.

**Experiment 2**
This experiment examined the effect of the patellar splitting approach on the retinacular tissues. Eight knees had the patella split and fixed as described above. Patellar kinematics was recorded before and after patellar splitting.
The transducers measured ligament length change in the MPFL, the lateral retinaculum, and the lateral patellofemoral ligament. The kinematic and transducer data before and after the split were analyzed every $5^\circ$ of flexion using a two-way repeated-measures analysis of variance across the range of flexion angles. Differences were examined with Bonferroni posttests and were assumed significant for $p < 0.05$.

RESULTS

Experiment 1
No significant difference was observed in the average MPFL length at the various flexion angles between the native knee and after closure of the patellar split and the medial parapatellar incision (Fig. 3). However, MPFL length change patterns were more variable with repeated use of the medial parapatellar incision than with the patellar splitting approach, as evidenced by the standard deviations. The standard deviations at the various flexion angles ranged from 0.01 to 0.18 mm for the native knee. After closure of the patellar split and medial parapatellar incision, they were 0.01–0.15 and 0.5–1.1 mm, respectively.

Experiment 2
The lengths of the MPFL, the lateral retinaculum, and the LPFL were not changed significantly ($p > 0.05$) by splitting and then reapproximating the patella (Fig. 4). No significant difference was observed for the tracking patterns before the patellar split and after closure of the split (Fig. 5). The standard deviations were relatively large because of the variability between the knees and not because of a difference between the before and after values of the patellar splitting approach. The statistical test accounted for this, because it was a repeated-measures test that determined the significance of the difference before and after the intervention for each knee.

DISCUSSION
The patellar split approach did not alter patellar tracking and ligament lengths of the extensor retinaculum. It can give excellent exposure of the knee, and can be opened and closed repeatedly with ease. Although not for clinical use, it has advantages in the laboratory. Because this approach does not violate the parapatellar soft tissues, it can be a useful model for the knee after it has healed from an articular surgery such as implantation of a prosthesis. Furthermore, as it can be opened and closed repeatedly with no effect on ligament length change and kinematics, additional procedures can be performed without the confounding factor of the tightness of the closure of the approach. For example, the effect of prosthesis component malposition can be explored. The medial parapatellar incision and closure can affect patellar tracking in total knee replacement surgery, explaining the differing lateral retinacular release rates in total knee replacement in the literature for different approaches to the knee.$^{14–17}$ Similarly, this may be the cause for the different recommendations that have been made regarding how the medial parapatellar incision should be addressed during the assessment of patellar tracking, ranging from not placing pressure on the patella and leaving the incision open to approximating the capsular incision in two locations.$^{18–24}$

The patellar split is relatively easy to perform. A small hand-held hacksaw with a narrow blade available in
hardware stores can be used, and is preferable to a power saw or a standard orthopedic oscillating or reciprocating saw. A cannulated drill system is not necessary, although it makes screw placement more predictable and precise, which is important when other fixtures are in place in the patella. In our case, the mounting for the patellar tracker was cemented in the anterior surface of the patella. One screw was therefore passed at a level proximal to and the other screw was passed distal to this mounting. If patellar resurfacing is planned in the experiment, for example, then the depth of screw placement is also critical. We have since performed total knee replacement including patellar resurfacing using this approach, which can be done by accurate placement of the screws, making sure the split in the patella is more laterally based. However, the split must extend distally into the substance of the patellar tendon along its fibers rather than to the lateral side of the tendon. Moreover, the more lateral the split, the smaller the lateral bone fragment, which makes the fixation more difficult. With repeated opening and closing of the patella, especially in porous bone, screw purchase on the far end can become poor. This problem can be overcome by using PMMA to rebuild the screw holes in the medial fragment or by using supplemental cerclage wires through the cannulated screws. Another option is to use cerclage wires rather than screws and to tighten the wires in a figure eight over the anterior patellar surface. Large diameter sutures can also be used. However, we have elected to continue to use the screw technique as the standard approach as it is quicker and less cumbersome to access the joint and close the split.

In summary, the technique we have presented is convenient and reliable for accessing the knee joint without significantly affecting the surrounding soft tissues and kinematics, making it useful for in vitro research.

ACKNOWLEDGMENTS
A.M.M. was supported by the University of Malaya Medical Centre, Kuala Lumpur, and the Arthritis Research Campaign (ARC). Knee specimens were obtained with funds provided by a grant from the ARC. K.M.G. was supported by a grant from Smith & Nephew (UK) Ltd. We thank W. Scott Selbie, Ph.D., Director of Research and Development, C-Motion, Inc., for his invaluable help and software support.

REFERENCES