Knee Surg, Sports Traumatol, Arthrosc
(2001) 9 : 330–336

DOI 10.1007/s001670100230

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Anterior and posterior cruciate ligament reconstruction in the new millennium: a global perspective

Received: 10 January 2001
Accepted: 9 May 2001
Published online: 8 August 2001
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Introduction

In May 2000 over 50 surgeons representing 18 different countries and 5 continents assembled in Pittsburgh, Pennsylvania, USA, for the Eighth Panther Sports Medicine Symposium. Entitled "From Robotics to Gene Therapy: Sports Medicine in the New Millennium," the symposium focused on both current perspectives and new and emerging technologies in the field of orthopedic sports medicine. Topics covered ranged from cruciate ligament reconstruction and meniscal transplantation to future directions and outcomes measurements in orthopedic sports medicine. The symposium also offered the unique opportunity of obtaining "a global perspective" on the current approaches used around the world for various sports related injuries. Eight global panels were held to provide an international viewpoint on topics such as cruciate ligament and posterolateral corner reconstruction, the dislocated knee, osteotomies about the knee, and return to play following ACL reconstruction. For each topic, each panelist gave a 6-min presentation describing his or her practice setting and patient profile, current techniques or approaches, and clinical outcomes. A 20-min question and answer session was then held (Fig. 1). Finally, the session moderator presented the panel "consensus" in which the results were summarized and tabulated. The feedback that we received in response to these panels from both confer-

Fig. 1 The 14 members of the ACL reconstruction panel participate in a question and answer session

ence faculty and attendees was especially positive, and there were several requests that we make these consensus summaries available.

The purpose of this article is to present the results of four of these global panels: ACL Reconstruction, Revision ACL Reconstruction, Return to Play Following ACL Reconstruction, and PCL Reconstruction. Our goal was to give the readership of *Knee Surgery, Sports Traumatology, Arthroscopy* an update on current techniques and issues of leading surgeons around the world. Each of the panelists included in this article has confirmed the data presented and has consented to be included in the summary. The current trends as reflected by each panel are described, including patient population, surgical techniques, rehabilitation, and clinical outcomes.

Panelist profile

The panelists participating in these four panels represent an accomplished assembly of surgeons and physical therapists with extensive experience in orthopedic sports medicine. On average, they have been in practice for 22±5 years (range 13–30 years). Among the 25 panelists featured in this article, 15 originate from North America, four from Europe, two from South America, two from Australia and New Zealand, one from Asia, and one from Africa. Eleven (40%) practice in an academic institution, six (24%) practice in a private setting, and nine (36%) describe their practice as having both academic and private components.

ACL reconstruction

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Patient profile

An average of 138±61 primary ACL reconstructions are performed each year by the 14 panelists (range 45–250). The average age of the patient receiving ACL reconstruction was 26 years and ranged from 8 to 70 years of age. Of these, 25±16% of the patients were described as professional or college athletes, 66±17% were recreational athletes, and 9±8% were described as nonathletes.

Graft choices

Graft choices for ACL reconstruction have evolved over the past decade. While patellar tendon autograft reconstruction with interference screw fixation was once the standard of care for these injuries, hamstrings and quadriceps tendon autograft and Achilles and patellar tendon allografts are increasing in popularity. Reflecting these changing trends, eight (57%) of the panelists use hamstrings grafts for the majority of their cases, with five (36%) preferring autograft patellar tendon and one (7%) using exclusively quadriceps tendon autografts. Allografts are used by only three of the panelists, representing only 2% of the total reconstructions on average. It is notable that 11 of the 14 panelists report using more than one type of graft depending on the context of the injury. Examples cited include the use of hamstrings tendons with open growth plates or the use of allograft for revision ACL surgery. However, each panelist clearly has a preferred graft choice, with 10 of the 14 utilizing the same graft in over 90% of cases.

Surgical technique

All of the surgeons perform ACL reconstruction arthroscopically, with eight of the panelists using a one-incision technique and four using two incisions. Two other panelists report that the number of incisions used is dependent upon their choice of grafts. One of the most variable issues surrounding ACL reconstruction is tunnel placement, especially on the femoral side. On the femur, 5 of 14 panelists "blow out" the posterior cortex of the intercondylar notch (near the over-the-top position), and 7 offset their tunnel by up to 7 mm from the cortical margin (Fig. 2). Another goes "over-the-top" and one directly through the lateral femoral condyle. The majority (eight) employ an 11:00/1:00 placement, and four panelists drill the femoral tunnel in a 10:30/1:30 position. One panelist places his tunnel at the 9:00/3:00 position, directly through the lateral condyle, and another performs an over-the-top reconstruction (Fig. 3). Tibial tunnel placement, on the other hand, is more consistent among the panelists. Eleven (79%) of the panelists place the tibial tunnel in the posterior or posteromedial aspect of the footprint of the ACL insertion, while the remainder place the tunnel off the tibial spine near the anterior horn (posterior aspect) of the lateral meniscus. Perioperative fluoroscopy is utilized by two of the surgeons, and postoperative radiographs are obtained by ten. Surprisingly, four surgeons do not obtain any radiographic verification of their tunnel placement.

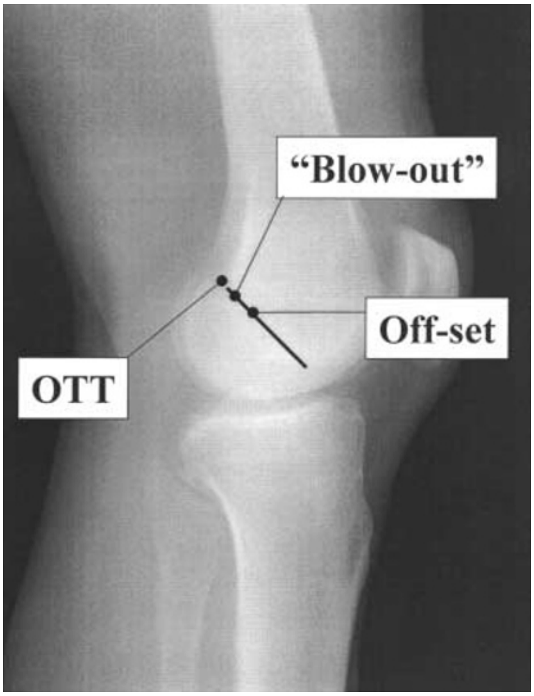

Fig. 2 Lateral radiograph demonstrating three placements for femoral tunnels for ACL reconstruction: *OTT* over-the-top; *Blow-out* blow-out posterior cortex; *Off-set* by up to 7 mm

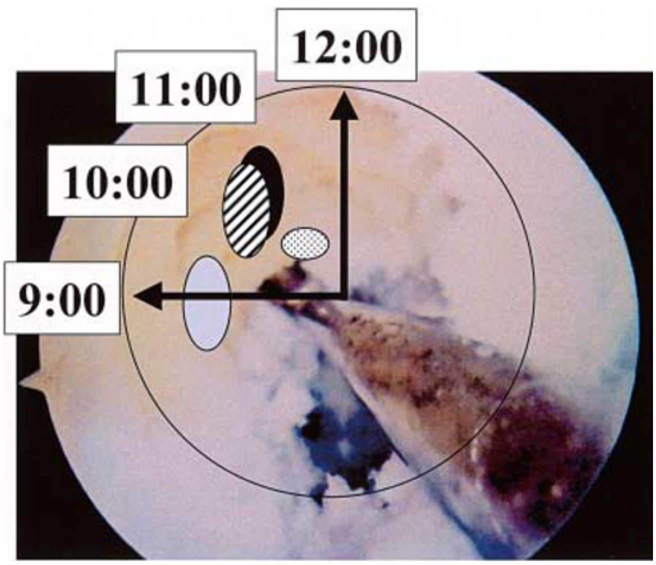

Fig. 3 Arthroscopic view of the lateral femoral condyle demonstrating options for femoral tunnel placement for ACL reconstruction

Table 1 Fixation methods used for ACL reconstruction (some authors use more than one fixation technique)

	n
Hamstrings grafts	
Femur	
Absorbable interference screw	2
Endobutton	6
Toggle	1
Staples	2
Press fit knots	1
Compression anchor	1
Bone disk	1
Tibia	
Absorbable interference screw	4
Screw/washer	2
Belt buckle	2
Staples	2
Suture or tape/post	1
Patellar tendon grafts	
Femur	
Interference screw	8[a]
Press fit	1
Endobutton	1
PLA screw/button	1
Tibia	
Interference screw	8[a]
Plate/screw	1
Suture or tape/post	
PLA screw/button	1

6 metal, 2 bioabsorbable

Graft fixation

As demonstrated in Table 1, graft fixation is variable and depends upon graft type, femoral versus tibial tunnel, and the surgeon. In general, hamstrings are more variable than patellar tendon grafts, with interference screw fixation used by eight of ten panelists who utilize patellar tendon autografts. Endobutton fixation on the femoral side is the most popular choice for hamstrings reconstructions, followed by bioabsorbable screw and staples. Other fixations used for the hamstrings graft on the tibia included staples, screw/post, bioabsorbable screw, and buckles. None of the experts uses the crosspin fixation technique. The majority of the panelists fix the graft with the knee at full extension (7 of 14, 50%) or 20–30° of flexion (5 of 14, 36%). One panelist reports fixing the graft with the knee at 80° of flexion, while another panelist fixes hamstrings grafts at 90° of flexion, but fixes patellar tendon grafts at 20°.

Clinical outcomes

With respect to outcomes, fewer than 5% of patients experience an extension loss greater than 5° or a flexion loss greater than 10°. Complications are not otherwise reported to be a major problem, although three panelists who use predominantly hamstrings grafts note a 6–16% rate of hardware-related complications while several who prefer patellar tendon grafts report graft site morbidity in up to 15% of patients. Other complications represent less than 1–2% of the cases and include wound healing and fixation failure. All of the panelists use a postoperative brace or splint following surgery and, in general, start range of motion exercises immediately. Perspectives on weight-bearing vary somewhat, with some starting immediately or as tolerated while others wait up to 2 weeks to begin full weight-bearing. There is considerable variability regarding return to activities as well, with patients returned to activities of daily living in 1–8 weeks and to sports in 3–12 months. Three of the panelists recommend the use of a functional brace, although several others do prescribe them for special cases, such as hyperextension injuries, patient request, or an early return to a cutting sport (i.e., 3–6 months).

With regards to clinical outcomes, 12 of the 14 authors regularly use the International Knee Documentation Committee guidelines and another uses it for publications. Other outcome scales used include the Lysholm, Tegner, and Cincinnati rating systems. Eleven panelists regularly include KT-1000 as part of their evaluation, and two others use it when evaluating patients for research studies. Overall stability data from the panelists who collect KT-1000 data indicate that 74±13% of patients are normal, 17±9% patients nearly normal, 7±5% abnormal, and 2±2% severely abnormal. The overall success rates include 88±7% with excellent or good results, 10±5% with fair results, and 2±3% with poor results.

Summary

It is clear that even among the "experts,", there are many differences. In the end, however, outcomes and return to play seem to be similar. Hamstrings tendons have gained increasing popularity (preferred by 57%). The reasons for this are probably the "new" biomechanical data on graft strength, improved fixation techniques, less donor site morbidity, and smaller incisions (improved cosmetic appearance). In addition, as most of the panelists are in a teaching environment, the technical aspect of hamstrings harvest, *once taught*, are similar and have less potential complications than patellar tendon harvest.

With respect to tunnel placement, regardless of graft choice, there remains subtle but significant differences on the femoral side. One surgeon places his tunnel at the 3:00/9:00 while another performs an "over-the-top" reconstruction (i.e., at 12:00). The remaining surgeons fall somewhere between these. This difference in large part may be explained by the more difficult orientation of the femoral insertions. Attitudes regarding tibial tunnel placement, on the other hand, are much more consistent, with all surgeons choosing a placement within the ACL insertion site. This is probably because the insertion site is more easily identified. The femoral tunnel insertion is an area that clearly requires further scientific investigation.

Revision ACL reconstruction

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On average 14% (range 3–25%) of the total number of ACL reconstructions performed by the five panelists are revision surgeries. It was generally agreed that technical error is the cause of failure for the large majority of primary ACL reconstructions, representing about 70% of the cases. Another 20% are a result of trauma to the knee, with the remaining 5% are believed to be due to other causes, such as failure of graft incorporation. The panelists are also in agreement with respect to their indications for performing revision ACL surgery, with all citing functional instability as their primary indication. Other indications include increased anterior laxity and painful loss of motion.

Graft selection for revision surgery is variable. Three of the panelists use only autografts while two others utilize more allografts but use autografts as well. Of the autografts used, patellar tendon is the most popular, being used by four of the five panelists, followed by hamstrings tendons. One panelist uses only autograft quadriceps tendon, and another occasionally uses the contralateral patellar tendon or reharvests the same patellar tendon used in the primary reconstruction. Of the two panelists who prefer allograft, the Achilles tendon represents over three-quarters of the reconstructions, with the remainder patellar tendon.

With respect to tunnel management for the revisions, techniques for the femoral tunnel include endoscopic, two-incision, and over-the-top techniques. Endoscopic is the method of choice, being used by all five panelists for some situations. Three panelists almost always use endoscopic techniques, while another uses endoscopic if the primary reconstruction is two-incision, and vice versa. One panelist uses an over-the-top technique with Achilles tendon allograft in the majority of his cases. It was generally agreed that bone grafting for expanded tunnels most often performed on the tibial side. The interference screw is the most commonly used fixation on the femoral side by three panelists, with the others utilizing Endobutton or Fastlok. Most of the panelists prefer an iliac crest bone graft for treating expanded tunnels. It was agreed that expanded tunnels should be treated in two stages by all panelists, waiting 3–6 months before performing the revision ACL reconstruction. Tibial fixation, again, is variable but includes interference screws (three panelists), staples, Fastlok plus cortical screw, and screw with soft tissue washer.

Postoperative management following revision ACL surgery is notably slower from that for primary ACL reconstruction, according to four of the five panelists, while the fifth reports no difference. Some of the differences cited are a longer period of non-weight-bearing, avoidance of hyperextension, and more time before returning to sports, if ever. Four of the five panelists also report that clinical outcomes following revision ACL reconstruction are worse than those for primary ACL reconstruction. The panelists report that on average only 60% of patients achieve excellent or good results, compared to the 88% cited by the panel for primary ACL reconstruction. Furthermore, 10% of the results are described as severely abnormal, compared to only 1–2% following primary reconstruction. Because of these results the majority of panelists felt that revision ACL surgery is a salvage procedure, and that return to sports should not be the primary reason for the surgery.

In summary, revision ACL surgery continues to be a challenging clinical problem. The majority of experts in this panel felt that the results are significantly worse than for primary reconstructions. A wide variety of grafts and surgical techniques are utilized. This reflects the complex nature of this problem. These cases should be treated differently than primary ACL reconstructions, and the surgeons must be prepared and experienced at a wide variety of different ACL techniques.

Return to play following ACL reconstruction

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Four experienced ACL surgeons and two accomplished physical therapists, with a combined average of 21 years in practice, described the principles which guide their decisions on return to play for athletes following ACL reconstruction surgery. Two treat primarily professional and collegiate athletes, while the others tend to see more recreational athletes.

Autograft patellar tendon is the graft of choice among the panelists, with only one therapist seeing more patients who received hamstrings grafts or allografts. Among those utilizing a patellar tendon graft, the metal interference screw is the preferred fixation. However, other fixations used include a press fit technique on the femur and a combination of a screw with sutures or a plate on the tibia. For those using hamstrings grafts, Endobutton fixation or a combination of Endobutton and nonabsorbable interference screw is used on the femur, and combined suture/post or absorbable interference screw/staple on the tibia.

The panel agreed that the immediate postoperative period (0–4 weeks) following ACL reconstruction should focus on reduction of pain and swelling, increasing range of motion, and progression from partial to full weight-bearing. Bracing is recommended during the first 2–4 weeks. Other important considerations mentioned during this early period include quadriceps and hamstring strengthening, patellar mobility, proprioception, and muscle control. Of note, one panelist also employs a preoperative program that concentrates on reduction of swelling, normalization of motion and gait, and patient education and preparation.

During the intermediate period (4–12 weeks postoperatively) continued improvements in range of motion and strength, and closed chain and functional exercises are among the priorities for rehabilitation. Other activities, such as running, swimming in a pool, and bicycling, also may be added. One panelist especially noted the importance of neuromuscular control drills and perturbation training during this period.

After 3 months the panelists focus their rehabilitation protocols primarily on continuing to improve strength, neuromuscular control, and progression to sport specific activities. Activities such as bicycling, jogging/running, and swimming were supported at this time, and two panelists instituted a plyometric exercise program at 10–12 weeks (i.e., jumping and landing exercises designed to increase explosive strength and power). It is important to note that these represent generalities, and that all of the panelists emphasize the importance of an individualized, athlete-, sport-, and sometimes gender-specific rehabilitation program.

The primary factors cited which determine when the athlete is allowed to return to the previous level of play include clinical examination, graft healing, and strength. Examination should reveal no effusion or pain and no excess laxity. Strength testing of the quadriceps should show a return of muscle function to 80–90% of the contralateral limb. One panelist noted that an earlier return would be permitted (i.e., 6–8 weeks) if quadriceps strength and knee outcomes scores for activities of daily living are both greater than or equal to 80%; otherwise, return would likely take closer to 12 weeks. Other factors taken into consideration include proprioceptive evaluation, hop tests, and muscle control. On average the amount of time before returning is 4.3 months for running (range 6 weeks–12 months), 6.5 months for jumping (3–12 months), 5 months for light sports (3–9 months), 5.8 months for moderate sports (4– 9months), and 8.1 months for strenuous sports (4–18 months).

With respect to functional bracing, one panelist consistently prescribes a neoprene sleeve to improve proprioception while another never recommends this, citing a lack of benefit. The remaining four may recommend a sleeve for proprioception or a functional brace for sports such as skiing and basketball, or when making the transition to cutting and running. For the therapists, this also depends upon the preference of the particular surgeon.

Four of the six panelists stated that their athletes are now returning to sports sooner than they did 5 years ago, while two report no change. One did note that the initial stages progressed more slowly, but that the return to play occurs more quickly. Reasons cited by the panelists for returning athletes to play sooner include improved knowledge on evaluation, treatment and healing of ACL injuries, and decisions to place more emphasis on neuromuscular training and proprioception.

PCL reconstruction

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The six panelists perform an average of 15±7 PCL reconstructions each year (range 7–23). In agreement with reports that the majority of PCL injuries are accompanied by concomitant damage to one or more other structures of the knee, three of the panelists report that over 75% of their reconstructions are performed on patients with combined injuries; two others report that they perform approximately equal numbers of isolated and combined PCL reconstructions. Revision PCL reconstruction represent 10% or fewer of the total cases performed, or only one or two cases per year for each panelist. The average age of the patient receiving PCL reconstruction is 30±3 years of age (range 8–63). Sports-related incidents accounted for approximately 60% of the injuries, followed by motor vehicle accidents at 25%.

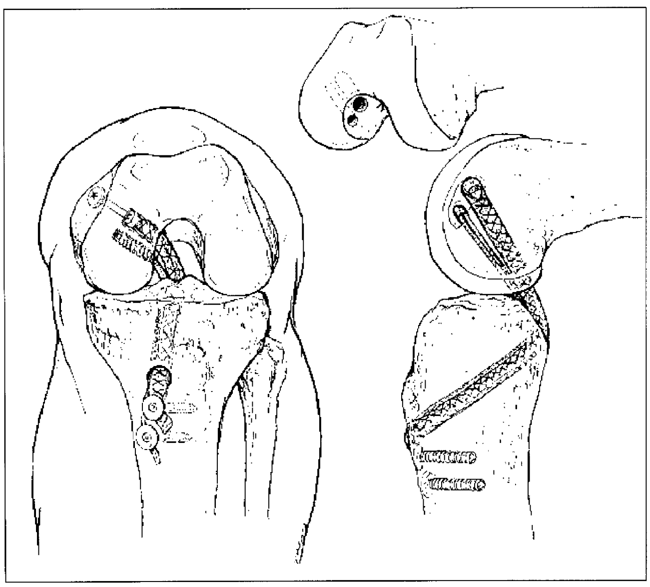

Fig. 4 Double-bundle posterior cruciate ligament reconstruction in which both the anterolateral and posteromedial components of the PCL are reconstructed. (From 7)

Over the past several years several new techniques for PCL reconstruction have emerged that are believed more closely to restore the normal anatomy of the intact PCL. These new reconstructions and several variations upon them are reflected in the techniques currently used by each panelist. With double-bundle PCL reconstruction, both the anterolateral (AL) and posteromedial (PM) components of the PCL are addressed (Fig. 4) [3, 5]. Although clinical data are still pending, several biomechanical studies have suggested that this technique better restores normal knee biomechanics than a traditional single-bundle reconstruction of the AL component [5, 8]. Another recently described technique, the tibial inlay reconstruction, involves direct fixation of the bone block of the graft into a rectangular trough cut into the insertion site of the PCL onto the tibia. This is believed to diminish the angle that results when the PCL graft is passed through a tunnel and fixed onto the anterior aspect of the tibia [1, 4].

Three of the six panelists utilize an anatomical double-bundle reconstruction of the AL and PM components using two femoral tunnels and one or two tibial tunnels. Autograft patellar tendon or allograft Achilles tendon is used for the AL component, while the PM component is reconstructed using either autograft or a combination of autograft and allograft semitendinosus tendon. Femoral fixation is usually achieved using interference screws and Endobutton for the two components, respectively. One or two tibial tunnels may be used, with tibial fixation consisting of a screw and soft tissue washer.

Two other panelists utilize the tibial inlay approach instead of a transtibial tunnel. One panelist uses a single bundle Achilles tendon or patellar tendon graft that is fixed onto the femur with a staple. Another combines the tibial inlay and double-bundle techniques, utilizing a split quadriceps tendon autograft. The two tendinous ends are fixed into anatomically placed tunnels in the femur using bioabsorbable screws plus a suture and post. Both fixed the bone block into a trough in the posterior tibia using a screw and washer.

A unique approach is taken by the sixth panelist by creating a 15×8 mm trough in the anatomical insertion of the PCL onto the femur. The bone block of a quadriceps tendon graft is wedged into this trough, and the graft is passed through a tibial tunnel and fixed using a screw, washer, and suture onto the anterior aspect of the tibia.

In general, the panelists place the tunnels in the anatomical location of the AL and/or PM components, although one prefers to use an isometric placement of the femoral tunnel. It was agreed that the graft used for single-bundle reconstruction or the AL component of the double-bundle reconstruction should be tensioned and fixed with the knee flexed (i.e., 70–100°). For those performing double-bundle reconstructions, the PM component is fixed with the knee at or near full extension (0–10°). This practice is in agreement with several recent biomechanical studies which have indicated that graft fixation of the AL component with the knee flexed provides the best restoration of normal knee biomechanics [2, 6].

With respect to postoperative rehabilitation, all panelists prescribe a brace that is worn for 10 weeks on average (range 3–16 weeks). Opinions are mixed with respect to beginning motion and weight-bearing. Three allow full passive range of motion within the first 3–4 weeks, while the others prefer a more gradual approach. Similarly, two panelists allow full weight-bearing immediately or within 1 week, while others recommended waiting 4–8 weeks before progressing from partial to full weight-bearing. Return to activities of daily living is generally achieved in 4–8 weeks (range 3–24 weeks), while return to sports takes patients 9 months on average (range 7–12).

In summary, there are certainly many differences with respect to reconstruction of the PCL. However, all of the panelists reached a consensus that more anatomical techniques are the goal. This is reflected by the development of double-bundle and inlay techniques, anatomical placement of the grafts in the insertion sites, and graft tensioning that more closely replicates the intact PCL.

Conclusion

In this summary we presented the results of four global panels on cruciate ligament reconstruction from the 2000 Panther Sports Medicine Symposium. The data presented in these summaries represent a general consensus of the opinions of the panelists for each area of interest and can therefore provide us with information on current perspectives and approaches to several common problems in orthopedic sports medicine. For example, there seem to be significant differences in femoral ACL tunnel placement, but agreement on tibial tunnel position. For PCL surgery, we are moving toward more anatomical procedures, with a uniform consensus on tibial and femoral tunnel placement but disagreement on fixation techniques. It is these similarities and differences in our approach to knee ligament injuries that these global panels were designed to address. We are hopeful that symposia such as these will stimulate new research areas on which our specialty can focus. The specialty of sports medicine is blessed with talented basic scientists and clinicians with research interests in knee anatomy, biomechanics, and surgical techniques. It is our hope that by presenting this information we can help our researchers to focus their talents on areas identified to be controversial. Finally, the ultimate test of how we are doing in solving these problems will come from our patients. Only prospective randomized studies will elucidate whether all of these variables play a significant role in our long-term clinical outcomes.

Acknowledgements We gratefully acknowledge each of the panelists for their participation in this endeavor, including their presentation at the Panther Sports Medicine Symposium and for verification of their data.

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