A Biomechanical Comparison of the Arciero and LaPrade Reconstruction for Posterolateral Corner Knee Injuries

Gehron P. Treme,* MD, Christina Salas,*†‡§ PhD, Gabriel Ortiz,*‡ MS, George Keith Gill,* MD, Paul J. Johnson,* MD, Heather Menzer,* MD, Dustin L. Richter,* MD, Fares Qeadan,|| PhD, Daniel C. Wascher,* MD, and Robert C. Schenck Jr,* MD

Investigation was performed at The University of New Mexico, Albuquerque, New Mexico, USA

Background: Injury to the posterolateral corner (PLC) of the knee requires reconstruction to restore coronal and rotary stability. Two commonly used procedures are the Arciero reconstruction technique (ART) and the LaPrade reconstruction technique (LRT). To the authors’ knowledge, these techniques have not been biomechanically compared against one another.

Purpose: To identify if one of these reconstruction techniques better restores stability to a PLC-deficient knee and if concomitant injury to the proximal tibiofibular joint or anterior cruciate ligament affects these results.

Study Design: Controlled laboratory study.

Methods: Eight matched-paired cadaveric specimens from the midfemur to toes were used. Each specimen was tested in 4 phases: intact PLC (phase 1), PLC sectioned (phase 2), PLC reconstructed (ART or LRT) (phase 3), and tibiofibular (phase 4A) or anterior cruciate ligament (phase 4B) sectioning with PLC reconstructed. Varus angulation and external rotation at 0°, 20°, 30°, 60°, and 90° of knee flexion were quantified at each phase.

Results: In phase 3, both reconstructions were effective at restoring laxity back to the intact state. However, in phase 4A, both reconstructions were ineffective at stabilizing the joint owing to tibiofibular instability. In phase 4B, both reconstructions had the potential to restrict varus angulation motion. There were no statistically significant differences found between reconstruction techniques for varus angulation or external rotation at any degree of flexion in phase 3 or 4.

Conclusion: The LRT and ART are equally effective at restoring stability to knees with PLC injuries. Neither reconstruction technique fully restores stability to knees with combined PLC and proximal tibiofibular joint injuries.

Clinical Relevance: Given these findings, surgeons may select their reconstruction technique based on their experience and training and the specific needs of their patients.

Keywords: posterolateral corner; knee; reconstruction; multiligament injury
allograft tendons. The results of their study demonstrated no significant difference between the intact and reconstructed knees with respect to varus translation or ER at any flexion angle. In 2005, Arciero published a technique in which the PLC was reconstructed with a fibular-based free soft tissue graft. The author noted in a clinical series that this reconstruction technique predictably restored VA and ER stability. To date, these techniques have not been compared with each other to evaluate their effectiveness in restoring stability to a PLC-deficient knee. Further investigation has also shown that stability of the proximal tib-fib joint plays a role in PLC repair and reconstruction outcomes. 

At our institution, patients with PLC deficiency undergo reconstruction with one of these 2 options, and discussions among our surgeons have raised the question of whether the LaPrade reconstruction technique (LRT) or the Arciero reconstruction technique (ART) is more effective in restoring patholaxity from these injuries. This study was designed and performed to answer this question and to assess whether reconstruction stability might be affected by proximal tib-fib instability or more dependent on an intact anterior cruciate ligament (ACL). Our hypothesis was that there would be no differences in the ability of the 2 reconstruction techniques to restore stability in ER and VA.

METHODS

Eight pairs of male, fresh-frozen knees (16 knees) from the midfemur to toe (mean age, 78.8 years; range, 55-95 years; Science Care Inc) that were free of visible knee pathology were purchased for use in this study. Prior to testing, the specimens were thawed at room temperature twice: once to perform specimen preparation and to harvest grafts for reconstruction and a second time to perform the reconstructions and testing. A senior orthopaedic surgical resident (P.J.J.) harvested the semitendinosus, gracilis, and Achilles tendons from each specimen to use as grafts for the corresponding reconstructions. The foot was disarticulated, exposing the articular surface of the distal tibia, and the skin and subcutaneous fat were removed. The knees and grafts were kept moist with saline throughout the testing procedure.

PLC Reconstruction Techniques

All dissections, sectioning, and reconstructions were performed by a sports medicine fellowship-trained orthopaedic surgeon experienced in multiligament reconstruction and familiar with both reconstruction techniques (G.P.T.). All tunnels were created with a cannulated reamer over a guide pin that was placed with described anatomic landmarks. Prior to fixation, all grafts were manually tensioned in the manner replicating the technique used during operative PLC reconstructions in our practice. All implants and No. 2 polyethylene core sutures used in the reconstructions were manufactured and donated by a single company (Arthrex).

The ART was completed as described by Arciero. A free semitendinosus graft was used for the reconstruction. Whist stitches were placed in each end of the graft to aid in graft passage. After identification of the femoral insertion sites, a 7 × 25-mm socket was created for the PLT and a 7 × 50-mm socket was created for the FCL. The fibular insertion sites of the FCL and PFL were identified, and a 7-mm tunnel was created from distal lateral to proximal medial through the fibular head to ensure adequate surrounding bone stock. One end of the graft was passed into the PLT socket and fixed with an 8 × 23-mm polyether ether ketone (PEEK) biotenodesis interference screw. The graft was then passed through the fibular tunnel from posterior to anterior and tensioned with the knee at 60° of flexion, neutral rotation, and a valgus stress applied. The graft was fixed in the fibular tunnel with a 7 × 23-mm PEEK screw. The graft was then passed into the FCL femoral insertion with a pull-through technique. The graft was tensioned with the knee at 30° of flexion, neutral rotation, and a valgus stress applied. The graft was finally secured with an 8 × 23-mm PEEK interference screw.

The LRT was completed as described by LaPrade et al. A split Achilles graft with 9 × 20-mm bone plugs was used for the reconstruction. A whipstitch was placed in the proximal end of each graft to aid in passage. Similar to the ART technique, the femoral insertion sites for the PLT and FCL were identified, and a 9 × 25-mm socket was created at each site. Likewise, a 7-mm fibular tunnel was created through the FCL insertion, exiting posteroMedially on the fibular head. Finally, a 10-mm-diameter tibial tunnel was created, originating between the Gerdy tubercle and the...
Mechanical Testing

A custom testing fixture (Figure 1) was fabricated that allowed mounting of the specimens at 0°, 20°, 30°, 60°, and 90° of knee flexion. The femur was rigidly fixed to the testing apparatus. An intramedullary rod was rigidly fixed at the distal tibia and the specimen was secured after alignment of the knee joint with the flexion axis of the fixture. A digital force gauge (FG-3008; Nidec-Shimpo) was used to apply a varus force perpendicular to the long axis of the rod. A 10-N-m varus moment was applied by measuring the length of the moment arm (knee joint to force gauge) and calculating the appropriate force needed to create a 10-N-m moment. A torque wrench attached to the intramedullary rod was used to manually apply a 5-N-m ER torque about the long axis of the rod.

Data Acquisition

Eight OptiTrack motion capture cameras (Prime 13 cameras, Natural Point Inc) were used to quantify VA and ER angular displacement about the knee. This was done with the use of rigid body marker sets placed on the tibial tuberosity, the anterior aspect of the femur (5 cm proximal from the knee joint), and the outside arm of the testing fixture located adjacent to its point of rotation. Motion capture software (Motive:Body; Natural Point Inc) recorded the initial and final positions of the marker sets. Custom Matlab software (MathWorks) was written to transform the data from a global coordinate system to a local coordinate system defined by the knee anatomy. Measurements were taken with no load, after application of a 10-N-m varus moment, and after application of a 5-N-m external tibial torque. After biomechanical testing in the intact state (phase 1), subsequent testing was performed after 3 sequential interventions: sectioning of the FCL, PFL, and PT (phase 2); PLC reconstruction (phase 3); and further sectioning of the proximal tib-fib joint (phase 4A) or the ACL (phase 4B). Four matched pairs had the proximal tib-fib joint sectioned, and 4 had the ACL sectioned. For every matched pair, 1 leg was randomized to the ART, while the contralateral limb underwent the LRT.

Data Analysis

Multivariate analysis of variance was used through the SAS system (SAS/STAT v 14.2, SAS Institute) to assess the mean differences over the 5 knee flexion angles between each phase (2, 3, and 4) and the intact state (phase 1), as well as between the ART and LRT reconstruction groups for each phase. The Wilks lambda statistic and a significance level of 5% were used to determine statistical differences. A post hoc parallel profile test was conducted to investigate if the 2 reconstruction profiles showed parallelism or a consistent difference across all flexion angles.

Second, an aggregate total of paired assessments was performed to detect if the ART or LRT technique more closely approximated intact stability for each knee in phase 3 and phase 4 in terms of percentage recovered ER or VA at post-reconstruction. The mean value for each specimen pair was compared at each flexion angle to identify which reconstruction most closely restored ER and VA to the intact state.

RESULTS

No statistical difference was found between the ER and VA data for the paired knees in an intact state (P = .57 and .77, respectively). This indicated no physiologic concerns in the specimens that might affect outcome data. It also allowed us to combine and establish baseline intact ER and VA profiles with the ART and LRT specimens at phases 1 and 2 of the study. After sectioning of the posterolateral structures (phase 2), there was a significant increase in ER (P < .0001) and VA (P = .02) laxity at all flexion angles. After PLC reconstruction (phase 3), there was no significant
difference in ER or VA laxity between the ART ($P = .51$) or LRT ($P = .69$) and the intact state. There was no significant difference between the ART and the LRT for either ER ($P = .48$) or VA ($P = .72$).

After sectioning of the proximal tib-fib joint (phase 4A), both reconstructions demonstrated increased laxity to the knee to a level near their post-sectioning, unreconstructed state. A comparison between ART and LRT data showed no statistical difference in ER ($P = .23$) or VA ($P = .18$) after tib-fib sectioning (Figure 2). After sectioning of the ACL (phase 4B), there was no significant difference in ER ($P = .85$) or VA ($P = .20$) laxity (Figure 3). ACL sectioning had no effect on ER but increased the VA stability of the knee beyond the intact state of the specimens.

A post hoc parallel profile test showed that the 2 techniques displayed parallelism for VA measures after tib-fib sectioning (phase 4A, $P = .99$). The LRT technique was able to restore stability near intact values more frequently than the ART technique for ER and VA (Table 1).

**DISCUSSION**

The importance of the PLC in knee function has been well established, and a thorough evaluation of these
structures in the context of knee ligament injuries is necessary to fully treat all patholaxity. Unrecognized or undertreated PLC injuries may compromise patient outcomes after reconstruction of other knee ligaments and may increase failure rates of these interventions. Given this importance, the PLC has been the subject of study regarding its anatomy and biomechanical properties as well as imaging characteristics. This knowledge has influenced our recognition of and treatment strategies for these injuries.

Acute injuries have been historically treated with repair, reconstruction, or a combination thereof. In a clinical series of 63 patients with PLC injuries, Stannard et al. demonstrated that reconstruction of the PLC performed superiorly to repair alone and recommended reconstruction in most cases. These findings demonstrate the importance of robust, functional, and anatomic reconstruction, although the most effective reconstruction method has not been fully defined. Reconstruction options have been described and various techniques explored and compared by many authors.

While no direct comparison of the ART and the LRT has been completed, several cadaveric biomechanical studies have compared various other surgical techniques to address PLC injuries. In a clinical series of 63 patients with PLC injuries, Stannard et al. demonstrated that reconstruction of the PLC performed superiorly to repair alone and recommended reconstruction in most cases. These findings demonstrate the importance of robust, functional, and anatomic reconstruction, although the most effective reconstruction method has not been fully defined. Reconstruction options have been described and various techniques explored and compared by many authors.

In our study, we found that intact testing and post–PLC Reconstruction Post–Tibiofibular Sectioning Post–ACL Sectioning Total

| Knee Flexion Angle | Post–PLC Reconstruction | Post–Tibiofibular Sectioning | Post–ACL Sectioning | Total |
|-------------------|-------------------------|-----------------------------|---------------------|-------|
|                   | LRT                     | ART                         | LRT                 | ART   | LRT  | ART  |
| 0°                | 5                       | 3                           | 1                   | 3     | 4    | 0    |
| 20°               | 5                       | 3                           | 3                   | 1     | 2    | 2    |
| 30°               | 5                       | 3                           | 2                   | 2     | 4    | 0    |
| 60°               | 3                       | 5                           | 2                   | 2     | 3    | 1    |
| 90°               | 3                       | 5                           | 2                   | 2     | 3    | 1    |

Varus angulation recovery

| Knee Flexion Angle | Post–PLC Reconstruction | Post–Tibiofibular Sectioning | Post–ACL Sectioning | Total |
|-------------------|-------------------------|-----------------------------|---------------------|-------|
|                   | LRT                     | ART                         | LRT                 | ART   | LRT  | ART  |
| 0°                | 5                       | 3                           | 4                   | 0     | 3    | 1    |
| 20°               | 7                       | 1                           | 3                   | 1     | 1    | 3    |
| 30°               | 2                       | 6                           | 4                   | 0     | 4    | 0    |
| 60°               | 5                       | 3                           | 3                   | 1     | 2    | 2    |
| 90°               | 7                       | 1                           | 3                   | 1     | 1    | 3    |

Values are presented as the number of LRT and ART reconstructions with restoration of stability closer to the intact state at each knee flexion angle for external rotation (top) and varus angulation (bottom) when matched pairs were compared. Sixteen tests were evaluated. ACL, anterior cruciate ligament; ART, Arciero reconstruction technique; LRT, LaPrade reconstruction technique; PLC, posterolateral corner.
most apparent increase in laxity occurred at the post–tib-fib sectioning phase. In this scenario, stability parameters were similar to the post-sectioning, unreconstructed state for both the ART and the LRT. This supports the findings of Jabara et al. in that a deficient proximal tib-fib joint compromises the integrity of the PLC and may result in failure of the reconstruction. The finding suggests that the proximal tib-fib joint should be stabilized in these situations to maximize the effectiveness of PLC reconstruction. A positive post hoc parallel profile test for VA after tib-fib sectioning indicated that a larger sample size may have elucidated a statistical difference between the techniques. This is not likely clinically important, however, since neither reconstruction was effective at restoring stability in this situation. It is important to note that after ACL sectioning, both techniques have the potential to restrict motion of the joint in VA. This becomes important clinically in situations where the PLC is reconstructed prior to final tensioning and fixation of an ACL graft.

In the evaluation of the aggregate total of counts in which either technique was better at approximating intact stability, the LRT technique was consistently closer to intact ER and VA measures than the ART at all flexion angles. According to multivariate analysis of variance, the outcome measure of this study had a medium effect size, $f^2(V)$, equal to 0.20. Based on this number, a sample size of 35 matched pairs would be needed to elucidate a difference between the techniques. This is not likely clinically important, however, since neither reconstruction was effective at restoring stability in this situation. It is important to note that after ACL sectioning, both techniques have the potential to restrict motion of the joint in VA. This becomes important clinically in situations where the PLC is reconstructed prior to final tensioning and fixation of an ACL graft.

The study was designed similar to other studies in the literature, and with the exception of the study by Rauh et al. it exceeded the number of specimens utilized in all of the other cited comparative studies as well as the original descriptive study by LaPrade et al. However, as these studies did not have a power analysis performed, they could not be used to assess power in the current study design. Alternatively, a pilot study could have been performed to determine power, but this option provided substantial additional financial obstacles that could not be resolved. A post hoc analysis demonstrated that with the addition of more specimens, a difference may have been seen in the data. While a study with this large number of specimens is possible, it presents considerable logistical and financial limitations while providing little clinical relevance to the small differences that might be found.

**CONCLUSION**

We can conclude that no statistical difference was found in the ability to restore ER and VA stability between the ART and LRT, although the study may have been underpowered according to post hoc analysis. We recommend that surgeons select their technique based on preference, training, and patient-specific scenarios, with less concern for surgical outcomes affecting PLC stability.

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