Return to Sport Following ACL Reconstruction With Slope-Correcting High Tibial Osteotomy in the Elite Athlete

Walter R. Lowe,* MD, Alfred Mansour,* MD, Steven Higbie,[†‡] PT, DPT, SCS, CSCS, Connor Galloway,[†] PT, DPT, MS, SCS, LAT, Jacquelyn Kleihege,[†] PT, MPT, SCS, and Lane Bailey,[†] PT, PhD

Investigation performed at Department of Orthopaedic Surgery, University of Texas Health Sciences Center, McGovern Medical School, Houston, Texas, USA, and Department of Sports Medicine and Rehabilitation, Memorial Hermann Health System, Houston, Texas, USA

Background: Increased posterior tibial slope is a strong predictor of anterior cruciate ligament (ACL) graft re-injury. A concomitant slope-reducing high tibial osteotomy (HTO) has been suggested to decrease re-tear risk in these cases although little is known regarding outcomes following ACL reconstruction with HTO, especially in elite athletic patients.

Indications: A 19-year-old National Collegiate Athletics Association (NCAA) Division 1 running back presented with an ACL tear, lateral meniscus tear, and posterior tibial slope of 19° (case 1). A 19-year-old NCAA Division 1 soccer forward presented with an ACL graft re-tear and posterior tibial slope of 21° (case 2).

Technique: Anterior closing wedge HTOs were performed along with a primary ACL reconstruction with quadriceps tendon autograft (case 1) and a revision ACL reconstruction with quadriceps tendon autograft (case 2). Following the arthroscopic procedures, an anterior approach was used to insert the first guide wire distal to the patellar tendon insertion from anterior to posterior aiming toward the posterior curve of the tibia. A second guide wire was placed at the previously templated distance. The osteotomy was then performed utilizing a saw and then osteotome. The reduction was performed by gently lifting the ankle anteriorly and applying axial pressure, and a new posterior tibial slope was calculated. After the osteotomy site was reduced, a preliminary reduction was performed by applying a clamp to both wires followed by placing a wire across the osteotomy site aiming from anterolateral to posteromedial. An anterolateral proximal tibial plate was applied, as well as a lag screw across the osteotomy site.

Results: At 6 months after surgery, case 1 demonstrated >90% Limb Symmetry Indices (LSI) with quadriceps strength, single leg hop tests, and change of direction tests. At 12 months after surgery, case 2 demonstrated >90% LSI with all functional testing and competed in 17 games. Both patients returned to preinjury performance metrics including top speed and vertical jump height. No significant postoperative complications or instability was observed.

Discussion/Conclusion: Primary or revision ACL reconstruction with HTO shows potential to assist athletes in returning to high-level sport while reducing posterior slope.

Patient Consent Disclosure Statement: The author(s) attests that consent has been obtained from any patient(s) appearing in this publication. If the individual may be identifiable, the author(s) has included a statement of release or other written form of approval from the patient(s) with this submission for publication.

Keywords: posterior tibial slope; ACL reconstruction; return to sport; osteotomy

VIDEO TRANSCRIPT

Thank you for watching this video. It is a brief video talking about return to sport following anterior cruciate ligament (ACL) reconstruction with slope-correcting high tibial osteotomy in the elite athlete.

As a background, this is just a simple presentation of 2 cases in very elite athletes. One after a failed previous ACL patellar tendon graft reconstruction, and the other in a primary reconstruction (both elite-level athletes). Case 1 is a 19-year-old Division 1 NCAA running back who has a primary tear of the ACL and a very complex lateral meniscus injury. Preoperatively, his posterior tibial slope is 19°, as you can see on the right. His procedure was an ACL reconstruction with a quadriceps tendon graft and lateral meniscus repair as these are all infra-tubercle slope-reducing

Video Journal of Sports Medicine (VJSM®), 3(5), 26350254231190938
DOI: 10.1177/26350254231190938

osteotomies, and we were worried about concomitant harvest of a patellar tendon graft in these cases. Case 2 is a 19-year-old NCAA Division 1 female soccer forward who also is a forward for the Canadian national team. It is a revision ACL reconstruction from a previous patellar tendon graft. She had a preoperative posterior tibial slope of 21°, and again she had a revision ACL reconstruction with slope-reducing osteotomy and a quadriceps tendon autograft done simultaneously.

What options do we have when we look at this? Protection from slope is still a little controversial with what we get from it. Certainly, we know with an increased posterior tibial slope, there is a linear increase in ACL stress.[2,4,5,7] Every 1° increase in posterior slope equals about a 20% increase in risk to the ACL reconstruction from the studies listed in the following paragraphs.[4]

As some background, slope-correcting high tibial osteotomy may reduce the risk of graft failure in these athletes.[1,3,6,8,9,11] What is known is that increased slope above 12° increases the risk of re-injury to the ACL graft.[2] What we do not know is how effective is this procedure for high-level athletes to return to their sport at the same level? What are the graft re-injury rates in these elite athletes? What are the return-to-sport/performance outcomes in these athletes? This last bullet point is what this video is about as there is definitely uncertainty in this group whether the combination of osteotomy and ACL reconstruction can lead to a return to their sport performance outcomes. Next, Alfred Mansour is going to describe the osteotomy technique that we have used in these athletes.

For the anterior closing wedge slope-reducing osteotomy, we prefer an infra-tubercle approach. Our goal for posterior tibial slope correction is between 6° and 10°. We typically choose an anterior approach, and we use a templated long-leg lateral radiograph to assess the amount of correction that we need. We will start by making the anterior approach and exposing the anterior aspect of the tibia, and then we will place our first guide pin just distal to the fibers of the patellar tendon insertion on the tibial tubercle. We then calculate the length for our osteotomy and then place a second pin (both of them directed at the posterior cruciate ligament (PCL) insertion posteriorly and superiorly). After we have placed the pins and confirmed that our appropriated wedge has been templated on a perfect lateral view, we use an oscillating saw and osteotomes to remove the wedge. After the wedge has been removed, we will gently hyperextend the leg, making sure that the posterior hinge stays intact and the osteotomy site gets compressed. We will then place a provisional pin and place our plate. Typically, an anterolateral plate (similar to a tibial plateau fracture) is used, but there are other options such as an anteromedial plate to secure the osteotomy site. We do place a tibial tubercle interfragmentary compression screw for added fixation and compression.

Indications for anterior closing wedge high tibial osteotomy in our practice include a prior failed ACL reconstruction with an increased posterior tibial slope greater than 12° without coronal malalignment. Contraindications for the anterior closing wedge high tibial osteotomy include knee hyperextension greater than 10°, multiligamentous knee injury, pre-existing tricompartmental arthritis, and an increased slope with preexisting coronal plane deformity. We use a multiplanar opening wedge osteotomy for combined deformities. In addition, multiple anterior closing wedge osteotomies have been described generally based on the relationship to the tibial tubercle, either being proximal to or distal to the tubercle, as well as involving the tubercle in the osteotomy.

After the completion of the intra-articular portion of the procedure, new drapes are donned, lateral posts are removed, and the limb is extended. An approximately 12-cm incision is created over the anterior leg extending from the inferior border of the patella to several centimeters distal to the tibial tubercle. Subcutaneous tissue and fascia are then incised. The anterior compartment is elevated off the anterolateral tibia with the use of electrocautery. The dissection is also carried out medially elevating soft tissue from the anteromedial tibia until one is able to place Hohmann retractors posterior to the proximal tibia medially and to the fibular head laterally. Now that the entire proximal tibia is exposed distal to the tibial tubercle, using fluoroscopy, a K-wire is placed just distal to the tibial tubercle directed obliquely proximally toward the PCL insertion.

Again using fluoroscopy, a second K-wire is placed distal to the first at the distance calculated during preoperative planning to remove the appropriate wedge. The wire is aimed in order to meet the tip of the proximal wire at the posterior cortex and should correspond to whichever angle was decided on as the correction in the preoperative planning. Following the K-wire placement, the osteotomy is performed using an oscillating saw initially with irrigation to reduce heat generation and then completed with osteotomes to provide more control over the completion of the osteotomy without violating the posterior tibial cortex. After the osteotomy is completed, the bone wedge is removed, the limb is extended slowly to maintain the posterior hinge, and then the 2 K-wires are clamped together. A provisional wire is placed across the osteotomy site to maintain the correction.

An anterolateral fixed angle plate is then positioned and provisionally fixed. Placement is confirmed on fluoroscopy, and screws are drilled and placed. Bone graft (both autograft from the wedge and allograft) are inserted in the

‡Address correspondence to Steven Higbie, Department of Sports Medicine & Rehabilitation, Rockets Sports Medicine Institute, Memorial Hermann, 6400 Fannin Street, Suite 1600, Houston, TX 77030, USA (email: steven.higbie@memorialhermann.org).

*Department of Orthopaedic Surgery, McGovern Medical School, The University of Texas Health Science Center at Houston, Houston, Texas, USA.

†Department of Sports Medicine & Rehabilitation, Rockets Sports Medicine Institute, Memorial Hermann, Houston, Texas, USA.

Submitted December 14, 2022; accepted June 30, 2023.

One or more of the authors has declared the following potential conflict of interest or source of funding: W.R.L. is a medical consultant for Arthrex and DonJoy, Inc; receives royalties from Arthrex; and has received consulting fees from Medinc of Texas. AOSSM checks author disclosures against the Open Payments Database (OPD). AOSSM has not conducted an independent investigation on the OPD and disclaims any liability or responsibility relating thereto.

osteotomy site to increase healing rate. Finally, a lag screw, through a lag by technique, is placed across the osteotomy site to provide further compression.

Postoperative radiographs demonstrate a well-fixed osteotomy, with a slope correction to 8°. The patient's incisions are inspected at 2-week follow-up. Her range of motion was 0° to 50°. She will remain nonweightbearing for an additional 4 weeks. At 1 and 2 months postoperatively, the slope is maintained, and the osteotomy appears well healed. The patient's range of motion has improved to 5° of hyperextension to 120° of flexion, with a firm 2+ Lachman. She has progressed to touch down weightbearing at 1 month and released to full weightbearing at 2 months.

So in the first case, this is our Division 1 running back on the right at 6 months. His self-reported function was 77.4%. His psychological readiness at 6 months was 72.8%, and Webster and Feller[10] from Australia has reported 55% to 65% is the normal psychological readiness at return to sport. Quadriceps strength was 94.3%, and hop testing was 94.3%. Change of direction testing was 100.9%. All these metrics were at 6 months. I would tell you which leg it was watching the video on the right, but I am not sure. Maybe you can tell me.

This is his straight ahead sprinting. We do have preinjury and postinjury performance metrics. His slope was changed from 19° to 5°. His preinjury top speed was 20.51 mph, and postoperative top speed at 6 months was 20.85 mph. His preinjury vertical jump was 25.0 inches, and postoperative vertical jump was 24.6 inches.

In the second case, at 1 year, the self-reported function was 97.6%. Psychological readiness was again very high at 79.5%. Single leg squat was 91%. Hop testing was 92.1%, and change of direction testing was 105%. Again, I would tell you which knee it was, but I cannot tell from watching this video.

This is the outcome at 12 months for this soccer player. She had a slope change from 21° preoperatively to 5°. Again she had a revision ACL with quadriceps tendon autograft. In her first season back, she played 17 games. You can see her preinjury vertical jump was 11.7 inches, and postoperative vertical jump was 11.5 inches. You can see her postoperative peak power was almost at the preinjury level. Her postoperative top speed was 17.3 mph. It is her right knee, so you can watch the aforementioned video to see her in-game performance.

In summary, the ACL plus slope-reducing HTO definitely holds potential for allowing high-level athletes to reach prior performance as exhibited by these 2 case reports. It is effective in primary and revision settings. We certainly recommend future research be conducted to confirm these results in larger cohorts, as well as assessing the re-injury rates.

Thank you very much for your attention.

REFERENCES

1. Akoto R, Alm L, Drenck TC, et al. Slope-correction osteotomy with lateral extra-articular tenodesis and revision anterior cruciate ligament reconstruction is highly effective in treating high-grade anterior knee laxity. *Am J Sports Med*. 2020;48(14):3478-3485.
2. Bernhardson AS, Aman ZS, Dornan GJ, et al. Tibial slope and its effect on force in anterior cruciate ligament grafts: anterior cruciate ligament force increases linearly as posterior tibial slope increases. *Am J Sports Med*. 2019;47(2):296-302.
3. Dejour D, Saffarini M, Demey G, Baverel L. Tibial slope correction combined with second revision ACL produces good knee stability and prevents graft rupture. *Knee Surg Sports Traumatol Arthrosc*. 2015;23(10):2846-2852.
4. Hendrix ST, Barrett AM, Chrea B, et al. Relationship between posterior-inferior tibial slope and bilateral noncontact ACL injury. *Orthopedics*. 2017;40(1):e136-e140.
5. Imhoff FB, Mehl J, Comer BJ, et al. Slope-reducing tibial osteotomy decreases ACL-graft forces and anterior tibial translation under axial load. *Knee Surg Sports Traumatol Arthrosc*. 2019;27(10):3381-3389.
6. Rozinthe A, van Rooij F, Demey G, Saffarini M, Dejour D. Tibial slope correction combined with second revision ACLR grants good clinical outcomes and prevents graft rupture at 7-15-year follow-up. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(7):2336-2341.
7. Salmon LJ, Heath E, Akrawi H, et al. 20-year outcomes of anterior cruciate ligament reconstruction with hamstring tendon autograft: the catastrophic effect of age and posterior tibial slope. *Am J Sports Med*. 2018;46(3):531-543.
8. Song GY, Ni QK, Zheng T, et al. Slope-reducing tibial osteotomy combined with primary anterior cruciate ligament reconstruction produces improved knee stability in patients with steep posterior tibial slope, excessive anterior tibial subluxation in extension, and chronic meniscal posterior horn tears. *Am J Sports Med*. 2020;48(14):3486-3494.
9. Sonnery-Cottet B, Archbold P, Cucurulo T, et al. The influence of the tibial slope and the size of the intercondylar notch on rupture of the anterior cruciate ligament. *J Bone Joint Surg Br*. 2011;93(11):1475-1478.
10. Webster KE, Feller JA. Development and validation of a short version of the anterior cruciate ligament return to sport after injury (ACL-RSI) scale. *Orthop J Sports Med*. 2018;6(4). doi: 10.1177/2325967118763763
11. Weiler A, Gwinner C, Wagner M, et al. Significant slope reduction in ACL deficiency can be achieved both by anterior closing-wedge and medial open-wedge high tibial osteotomies: early experiences in 76 cases. *Knee Surg Sports Traumatol Arthrosc*. 2022;30(6):1967-1975.