Justin Arner: Welcome, everyone. I'm Dr. Justin Arner from the University of Pittsburgh Medical Center in Pittsburgh, Pennsylvania. Today, I have the pleasure of speaking with Dr. Drew Lansdown, Assistant Professor in the Department of Orthopedic Surgery at the University of California, San Francisco. Dr. Lansdown was a senior author of the paper titled 'Multiple Tibiofemoral Bone Shapes Predict Outcomes After Anterior Cruciate Ligament Reconstruction: a Systematic Review,' which is in press in the Arthroscopy Journal. Welcome, Dr. Lansdown, and thanks so much for joining me.

Drew Lansdown: Thanks so much, Justin. It's really a pleasure to be here and look forward to talking about the study.

Justin Arner: Yeah, this is great. First of all, congratulations on a great study bony morphology with the ACL and other ligamentous injuries, certainly as you know, play a huge role, and I don't think we totally understand it. Can you give us a little background to how you got interested in this topic and why you decided to delve deeper in it?

Drew Lansdown: Yeah. My first exposure to the role of bone shape on the knee joint, I think interestingly enough, came from experience with our dog. And he had essentially an ACL injury, and the treatment proposed was a slope leveling osteotomy, which I was surprised by. I think I was either just starting medical school or just starting residency or in medical school and would've anticipated just ACL reconstruction, but with the anatomy of dog, the joint is so dependent on the ACL that the most predictable treatment is an osteotomy to level the slope so the knee is no longer that dependent on the ACL. And without that some dogs can't walk, the joint breaks down, and really impactful injury. That was, kind of on a personal side, first exposure to even that concept.

And then in a research setting, one of my collaborators, Dr. Valentina Bedoya, who's co-author on this paper, she was looking at statistical shape modeling and looking to apply that to patients with ACL injuries. And it's a really innovative technique that lets you analyze shape features without specifying ahead of time exactly what you're looking for. It's a really interesting way to analyze these complex differences in shape. And then, that got me really interested in looking into this more and what is known on the topic and where could we go with this in the future?

Justin Arner: Yeah, I think that's really insightful. One funny story for legacy of Dr. Fu. I remember when I was a young resident, he kind of found out the same thing and had one of the visiting medical students take this whole presentation about dog ACLs and slope correcting osteotomies. And it is interesting just implants with dental implants and things, how much we learn from each other. It's a great, great background. That's interesting. You mentioned in the manuscript, the difference in the bone morphology data regarding risk factors for injury to the ACL, which obviously is different than outcomes and issues after ACL reconstruction. Can you tell us a little bit about the risk factors for injury versus issues after ACL reconstruction?

Drew Lansdown: Yeah. Dr. Musahl from Pittsburgh, he had a recent systematic review in JBJS in 2020, that was on the risk factor specifically for an ACL injury. And he's done a lot of work in this area too, and definitely a real leader in that role of bone shape, but it's a great review of a number of different factors that can contribute to patients being more at risk to ACL injury. The idea behind this study was really looking at our outcomes after ACL reconstruction. We know that larger group of patients with ACL injuries, they may have certain features common, but then what about that subset that they re-tear after ACL reconstruction or we know that a certain fraction of patients will have poor outcomes or limited ability to return to sports and then always the downstream effect of posttraumatic arthritis. And what are the data that are behind our understanding of what may contribute to those negative outcomes specifically after ACL reconstruction?

Justin Arner: Yeah. It's an interesting difference, and certainly an important one. Can you tell us a little bit about what you found in your systematic review, a summary of it?

Drew Lansdown: Yeah, definitely. And I think the biggest takeaway of this review, we were able to include 24 studies, almost 2000 total patients between ACL reconstructed or control knees. And the most consistent feature that I think we found was the tibial slope. And the other features that were evaluated included notch morphology, femoral condyle morphology, trochlea morphology, and then a miss mash between the tibia and the femur. But really the studies on tibial slope were more consistent in identifying with that as a potential negative risk factor for predisposing patients to failure after ACL reconstruction.

Justin Arner: Yeah. That's great. Yeah. I think those are good summaries. And the tibial slope is certainly the most we talk about clinically. That's interesting and good to hear we have some more data. You mentioned the imaging in your study and certainly you're one of the leaders in high level imaging. I'm interested to see your take and what types of imaging modalities were used to perform these measurements and what are your thought about the best methods to basically do that in the future and what's kind of the most reliable method to do that.

Drew Lansdown: For this study, 10 of the studies were x-ray based and then 10 were MRI and then four used CT scans. And I think first off being able to use three-dimensional imaging clearly gives us better resolution and an ability to discern, especially more complex shape features. I think our x-ray measurements can often be limited and imprecise. And then so much is dependent upon the projection, if we're getting good x-rays, and then there's certain errors with the measurements themselves. The x-ray, it's cheap, easy, available. Certainly, a good tool in some regard, but for a study on these more complicated shape features, I think x-ray can certainly be limited. And then between CT and MRI, I think historically CT has been able to give us better bony resolution, but we have been able to do a lot with MRI bone shape modeling.

And I think, especially for ACL patients where MRI is kind of our standard of care before surgery, if there is something in their post-op recovery, it's an MRI, not a

CT scan that we're routinely getting. But being able to use those types of scans that are already obtained and being able to process them to analyze these shaped features. And I think the cross-sectional imaging with an MRI is probably the most available and then gives us really the information that we need. Can be a little harder to process versus a CT scan, but still give a lot of good information about the shape.

Justin Arner: Yes, certainly. UCSF, you guys have done a lot of really cool MRI studies and that would be the holy grail to have some really high quality segmentation that's automatic with MRI and certainly the same stories with the shoulder, with bone loss and everything as you know better than anyone. That's great thoughts on the horizon. You mentioned there was a big variation with a lot of studies in general and also this topic in the terminology and methodology in the studies. You really couldn't perform an inadequate meta-analysis. Can you talk to us a little bit about the variations and everything in the different studies and what kind of clouded those evaluations?

Drew Lansdown: Yeah. I think for a good meta-analysis, you really want to have comparable patient groups, comparable outcome scores, comparable measurements so then you're really pooling data and able to draw those broader conclusions. And with this, there was just so much variability in the studies. Some of the imaging was done before surgery, some of it was done after, we talked about the different imaging modalities, some with MRIs, some CT, some x-ray. And then the different outcome measures, failure was consistently reported, just as ACL graft rupture. But then some of the studies looked too at just patient reported outcome scores. And then we also looked at markers of early post traumatic arthritis and being able to pool all of that, there weren't adequate numbers to really draw those broader conclusions and we hadn't thought that. The most meaningful way to present it would really just be as more of just that summary and that systematic review format.

Justin Arner: Yeah, totally agree. Great explanation of that. Some of us aren't as knowledgeable about these different ways to do these studies. That's great. Would you mind telling us about the most evidence, you kind of mentioned tibial slope, kind of dive a little bit more into depth about that regarding bony morphology and poor outcomes. What are kind of things you think clinically we should measure, can we measure or what we should look at boiling this down to more clinical aspects of what you found and how you think a surgeon should look at everything.

Drew Lansdown: Yeah. And I think, especially when evaluating a patient with a failed ACL, I think it really is important that we pay attention to tibial slope, especially. Measuring that either on x-ray, on MRI, or CT scan, if that's ordered as well. And I think it's been born out relatively consistently that tibial slope above 12, 13 degrees will put that patient at risk for retear ACL failure, graft tear. And I think, especially when facing that revision situation, it's probably worth considering an osteotomy even to correct that at that point. And so, I would definitely routinely evaluate that. And I think that's the one that we have the best evidence for at

this point. And when approaching a failed ACL, there's so many potential factors that go into what caused failure. Can be poor tunnel position, inappropriate graft selection, using an allograft in a young patient- it can be noncompliance or early return to sports, various valgus malalignment in the chronal plane, meniscus deficiency, MIS ligamentous injury. And so I think making sure if their slope is high, they're still going through these other potential issues and really identifying all of them that could possibly contribute to their failure. And then, correcting those that we're able to, and that are abnormal probably will give us the best chance to have a successful revision reconstruction.

Justin Arner: Yeah, that's excellent. That's another question I had for you. It really seems the best way to do systematically, go through every reason for failure in your mind to make sure in a busy clinic, you're not missing an alignment situation that you didn't look at it in the day of surgery or wishing you spent more time on this imaging or that type of imaging to really make sure you're prepared. That's a great explanation. Another question I wanted to ask you, you were hinting at, tibial slope is really the thing we can work on and improve the most. Based on your experience with this and all the imaging studies you do, do you think that anything is on the horizon regarding morphology of the femoral condyles or the mismatch, as you mentioned, between the tibia and femur and knot size. Do you think some of that'll be catching on in five or 10 years or things slowly that will come out of further research that maybe in a few years, just like tibial slope, wasn't really a big consideration 10 years ago that we'll be thinking about in the upcoming years?

Drew Lansdown: Yeah, I do. And I think kind of a long-term vision for work like this would really be in either the revision or even the primary setting, being able to say these are the factors that are going to put this any more at risk for re-injury. And then what are the things that we can do to mitigate that? And I think some thoughts in that area, so certainly not proven out yet, but I think worth investigating is in general, we know we don't want to use a graft less than eight millimeters for a hamstring or quad patellar tendon. It would try to stay away from anything smaller, but are there some patients where even that's going to be insufficient, we need a larger graft or somewhere there's going to be too much impingement and going a bit bigger is going to be worse for them?

And really finding that patient specific graft size. And then also I think graft type, potentially we could clarify if with this group of features, your knee will perform best with quad autograft, for instance, or something else. And then I think also there's been so much interest with the lateral extra articular tenodesis or these extra capsular reconstruction procedures and really defining the appropriate role for them or who will benefit the most. And it may that if you have this specific condyle or morphology, make sure we can't change that, but by adding the LET, maybe we protect the graft, add some extra stability. And now, that's the group of patients where we can identify them ahead of time and then do a little something extra to limit their failure rate. Or it could even be on the rehabilitation side that this group, we need to slow them down a bit more to let the graft mature, or maybe we can be more comfortable with an accelerated

rehab because this patient has these set of features that we can be confident that the graft isn't going to be over stressed in that regard and can move a little faster.

I think it's a really interesting area with a lot of different directions that are certainly unexplored, but I could see getting to the point where a lot of these are identified automatically and we say you have this profile, this is kind of that risk assessment. And then this is ideal graph size. Should we use an extra articular procedure? What's your rehab time course, all those other things we can kind of define going forward.

Justin Arner: Certainly. Yeah, that would be ideal. That's a great vision. And certainly it's exciting, think of how many ACL studies have been done, but still we have more work to do. And probably as you know, Dr. Fu would give a lot of lectures about individualized ACLs just like you were talking about measuring the hamstring size, quad size, the thickness of this graft, that graft, and you would measure the notch and adjust the graft accordingly. And you mentioned in your paper, larger notch width was associated with some poor outcomes. Distilling this down is certainly not easy, but exciting with all the different machine learning and technologies that are coming about. And yeah, that's a certainly a great explanation.

I think you really covered a lot of the questions I had for you today. I was curious if you had any other closing thoughts and ideas about bony morphology and ACL surgery in general, or thoughts in your practice about CTs to evaluate a tunnel position and width and all that when you're doing, especially revisions. Any thoughts and words of wisdom would be appreciated.

Drew Lansdown: Yeah. And for tunnel widening, I will always measure it on x-ray. And I feel like combining an AP and a lateral, you can usually get a pretty good sense of what those tunnel diameters will be. And then also looking at it on MRI, if there's something that just doesn't look right, then I always have a lower threshold to get a CT scan, but for most, I feel I'm not. And then just even assessing it intraoperatively, making sure that I have good bone to work with and bone grafting if needed, and hopefully just revising in a single stage if that's appropriate. But I always think more information going into it can only let you make better decisions. If there's anything that can be obtained on the imaging, it's probably worth doing. Other thoughts in this direction, I think one of the really interesting directions too, is that area of statistical shape modeling.

A lot of the features in this paper, is somebody saying I think that the notch width is important or the height or the tibial slope. It's us as researchers, or as surgeons saying, these are the factors I want to measure. And then the statistical shape modeling, that approach is saying these are the common features in this data set and what's different between these groups? And so you're kind of removing that potential bias. And then really, it may be something that's more complex than we can just easily measure, but it may be the factor that really is separating patients into those who fail and who do well.

I think there's a lot of potential in that direction too to kind eliminate some of our preconceived notions and hopefully get to the real underlying pathologic condition that may be putting patients more at risk for failure.

Justin Arner: Yeah. That's super insightful and appreciate your expertise and knowledge. And we look forward to all the exciting things coming out of UCSF and imaging, and you guys are very progressive with your studies. I appreciate your time today and thanks for sharing all your information with us.

Drew Lansdown: Yeah. Well, thanks so much for having me and great talking about it. And it's been fun.

Justin Arner: Dr. Lansdown's article entitled 'Multiple Tibiofemoral Bone Shapes Predict Outcomes After Anterior Cruciate Ligament Reconstruction: a Systematic Review' is press in the Arthroscopy Journal and is available online at www.arthroscopyjournal.org. Thanks so much for joining us.

Justin Arner: The views expressed in this podcast do not necessarily represent the views of the Arthroscopy Association or the Arthroscopy Journal.