Original Article

Tunnel Overlap Occurs 25% of the Time With Simultaneous Anterior Cruciate Ligament Reconstruction and Lateral Meniscal Root Repair

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Purpose: To assess the risk of socket-tunnel overlap for posterior medial or lateral meniscal root repair combined with anterior cruciate ligament reconstruction (ACLR) using artificial tibias and computed tomography scans for 3-dimensional modeling. **Methods:** Artificial tibias (n = 27; n = 3/subgroup) were allocated to groups based on inclination of socket-tunnels (55°, 60°, 65°) created for posterior root of the medial meniscus (MMPR) and lateral meniscus posterior root (LMPR) repair, and ACLR. Three standardized socket-tunnels were created: one for the ACL and one for each posterior meniscal root insertion. Computed tomography scans were performed and sequentially processed using computer software to produce 3-dimensional models for assessment of socket-tunnel overlap. Statistical analysis was performed with Kruskal-Wallis and Mann-Whitney *U* tests. Significance was set at $P < .05$. **Results:** The present study found no significant risk of tunnel overlap when drilling for combined ACLR and MMPR repair, whereas 7 cases of tunnel overlap occurred between ACL tunnels and LMPR (25.9% of cases). No subgroup or specific pattern of angulation consistently presented significantly safer distances than other subgroups for all distances measured. **Conclusions:** This study demonstrated 25.9% rate of overlap for combined LMPR repair and ACLR, compared with 0% for MMPR repair with ACLR. Lower ACL drilling angle (55 or 60°) combined with greater lateral meniscus drilling angle (65°) produced no socket-tunnel overlap. **Clinical Relevance:** Socket-tunnel overlap during meniscal root repair combined with ACLR may compromise graft integrity and lead to impaired fixation and treatment failure of either the ACL, the meniscus, or both. Despite this, risk for socket-tunnel overlap has not been well characterized.

The posterior root of the menisci is the part of the posterior horn through which the meniscus is securely anchored to the tibia.[1,2] The integrity of this structure is essential for the meniscus to perform its functions such as load transmission, shock absorption, joint lubrication, nutrient distribution, and to act as a secondary knee stabilizer.[3-10] In contrast, meniscal root tears, defined as either tears within 10 mm of the meniscal attachment or a soft- tissue/bony avulsion of the meniscal attachment, are biomechanically comparable with a complete meniscectomy.[10-13] These injuries result in decreased tibiofemoral contact area, abnormal high-peak contact pressures, and may lead to degenerative changes.[12,13] The prevalence of posterior meniscal root tears identified during arthroscopy has been reported to be 7% to 9% of meniscal tears in general, with most injuries (approximately two-thirds) occurring to the posterior root of the medial meniscus (MMPR).[13] Meniscal root tears have historically been difficult to identify, however, with recent studies suggesting the actual prevalence to be much greater. Overall, lateral meniscus posterior root (LMPR) tears are more frequently associated with ACL injuries (approximately 6 times more common than MMPR), while injuries to the MMPR are more frequently

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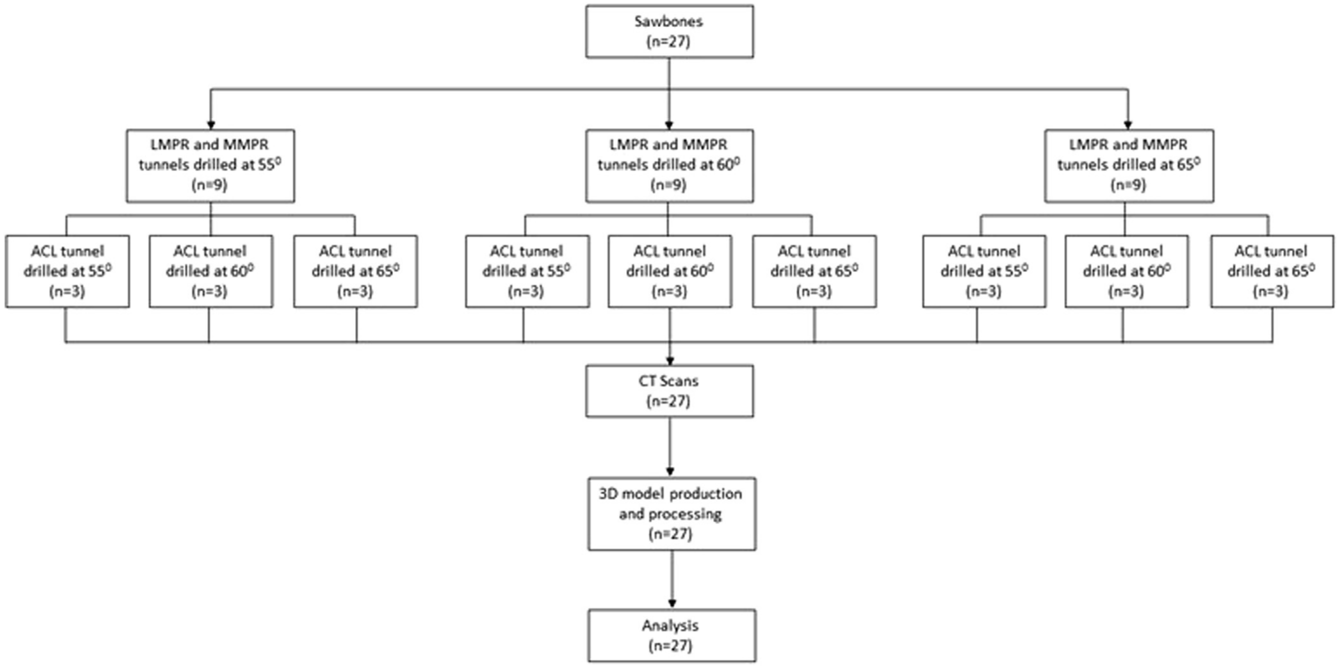

Fig 1. Flowchart for study samples examined in assessing the risk of tunnel overlap during simultaneous posterior medial or lateral meniscal root repair and ACL reconstruction. (ACL, anterior cruciate ligament; CT, computed tomography; LMPR, lateral meniscus posterior root; MMPR, medial meniscus posterior root.)

associated with cartilage injuries, and degenerative changes within the knee (10.3 times more than LMPR).[12,14]

Historically, root injuries were treated with partial or complete meniscectomy.[2,15] However, more recent studies have shown that the absence of the meniscus may lead to the development of knee osteoarthritis and results in a 132-fold increased risk of requiring a total knee replacement. This has led to an increased interest in meniscal preservation.[14,16,17] This is particularly important in cases of combined meniscal and anterior cruciate ligament (ACL) deficiency, as joint function and biomechanics become more severely compromised if both structures are deficient.[8,18,19] It is expected that more than 85% of patients with combined meniscal and ACL-deficient knees will develop arthritis in the long term.[15,20-22] Due to the biomechanical interdependence between the ACL and the meniscus, patients with this combined deficiency may benefit from meniscal posterior root repair with simultaneous ACL reconstruction (ACLR).

Posterior root repair may be performed through a transosseous fixation technique or with an anchor repair technique.[14] Simultaneous surgery for meniscal root tears and the ACL involves increased surgical duration and greater risk of complications, such as tunnel overlapping.[23,24] The meniscal root transosseous repair technique requires a transtibial tunnel to obtain fixation, which may potentially converge with an ACL tunnel or socket. Tunnel convergence should be avoided, as it may compromise graft integrity, or lead to impaired fixation and treatment failure.[25] However, it is currently unknown what the best combination of tunnel drilling is to best minimize tunnel convergence with regards to tibial tunnel guide angle and socket depth for both the ACL and meniscal roots. Therefore, the purpose of this study is to assess the risk of socket-tunnel overlap for posterior medial or lateral meniscal root repair combined with ACLR using artificial tibias and computerized tomography (CT) scans for 3-dimensional (3D) modeling. We hypothesized that socket-tunnels for ACLR would have greater risk of overlap with LMPR repair than MMPR repair regardless of the tunnel drilling parameters.

Methods

Sample Allocation and Tunnel Creation

Twenty-seven right artificial tibias (Sawbones, Vashon Island, WA) were allocated into 3 groups based on the inclination with which the tunnels used for simulating meniscal root fixation were drilled. The guide angulations studied were 55°, 60°, and 65° ($n = 9$ for each group) using a standard ACL drill guide with respect to the sagittal plane. These are the angles most commonly used by the senior authors. Each of these groups was subdivided into 3 subgroups, based on the inclination used for creating the ACL tibial tunnel. The angulations used for simulating tibial tunnel in ACLR were the same studied for tibial tunnels used for

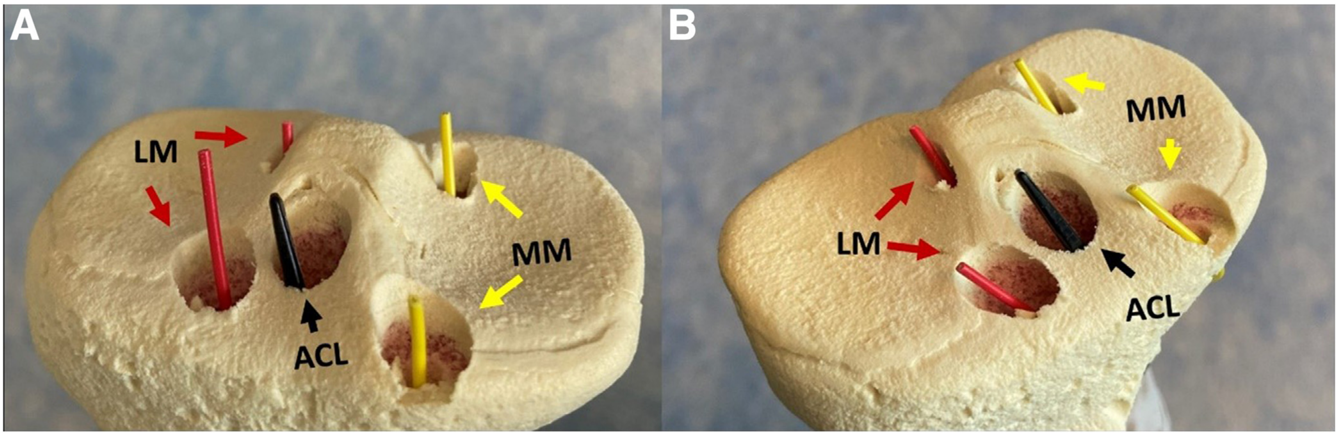

Fig 2. Anterior (A) and oblique (B) views of the proximal aspect of an artificial tibia after drilling the socket-tunnels. (ACL, anterior cruciate ligament; LM, lateral meniscus; MM, medial meniscus.)

meniscal root fixation: 55°, 60°, and 65° (n = 3 for each subgroup) (Fig 1). All angulations mentioned represent the relative inclination of the tunnel in relation to the plane of the articular surface of the proximal region of the tibia. Sample size was chosen to allow for adequate studies in each subgroup while also minimizing excess cost of the study. It was thought that this was an adequate sample size when compared with other studies.[26]

Socket-tunnel creation was performed by a single fellowship-trained orthopaedic surgeon (S.D.F.) and consisted of drilling tunnels for the posterior roots of the lateral and medial menisci using the transosseous meniscal root repair technique,[27] as well as creating a tibial tunnel for anatomic single-bundle ACLR based on an all-inside suspensory-fixation technique,[28,29] totaling 3 socket-tunnels in each tibia (Figs 2 and 3). The aim was to simulate ACLR in a context of simultaneous meniscal posterior root repair of either meniscus. Specimen was held in a vice grip for drilling to standardize positioning. Sockets were created using a tibial ACL drill guide (Arthrex, Naples, FL) and a commercially available retrograde reamer drill (FlipCutter; Arthrex). The entry point for all tunnels was located on the anteromedial tibia in accordance with the designated guide angle and socket location with the tibial guide placed to exit within the anatomic "footprint" of the respective meniscus root or ACL insertion, respectively. The "tunnel" was defined as the initial drilling with the un-flipped retrograde reamer, whereas the "socket" was the depth drilled retrograde from the articular surface. Tunnel diameters were all 3.5 mm in accordance with the unflipped standard reamer diameter, and lengths were determined by entry point, guide angle, and required socket location and depth. The sockets were created by retrograde drilling along the tunnel axis using the adjustable reamer blade set to clinically relevant socket diameters and depths for concurrent ACLR and meniscal root repair, as follows: ACL: 9 mm (diameter) and 25 mm (depth); posterior meniscal roots: 6 mm (diameter) and 10 mm (depth).

Imaging and Formatting

After socket-tunnel creation, helical CT imaging of each tibia was performed in a Toshiba Aquilion 64 scanner (Canon Medical Systems USA, Tustin, CA) using a bone acquisition protocol at 0.5-mm slice thickness and spacing, under the supervision of a single radiologist, blinded to specimen allocation. CT imaging

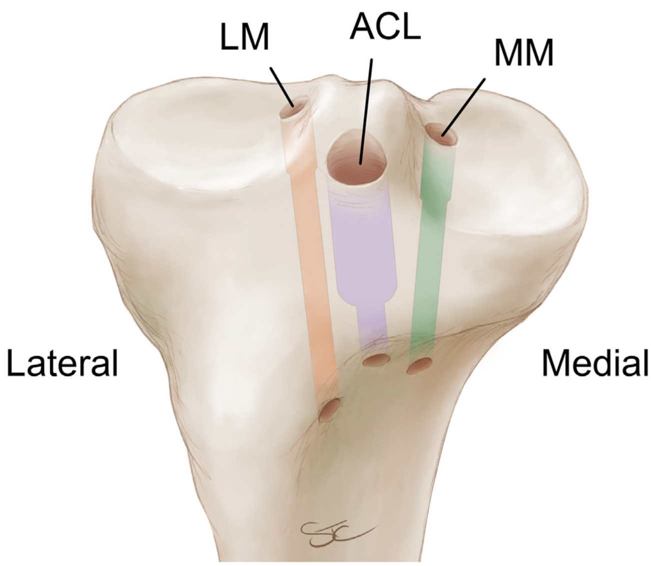

Fig 3. Assessing the risk of tunnel overlap during simultaneous posterior medial or lateral meniscal root repair and ACL reconstruction. Illustration depicting the proximal aspect of the tibia after socket-tunnel creation for ACL reconstruction (purple), MMPR repair (green), and LMPR repair (orange). (ACL, anterior cruciate ligament; LM, lateral meniscus; MM, medial meniscus.)

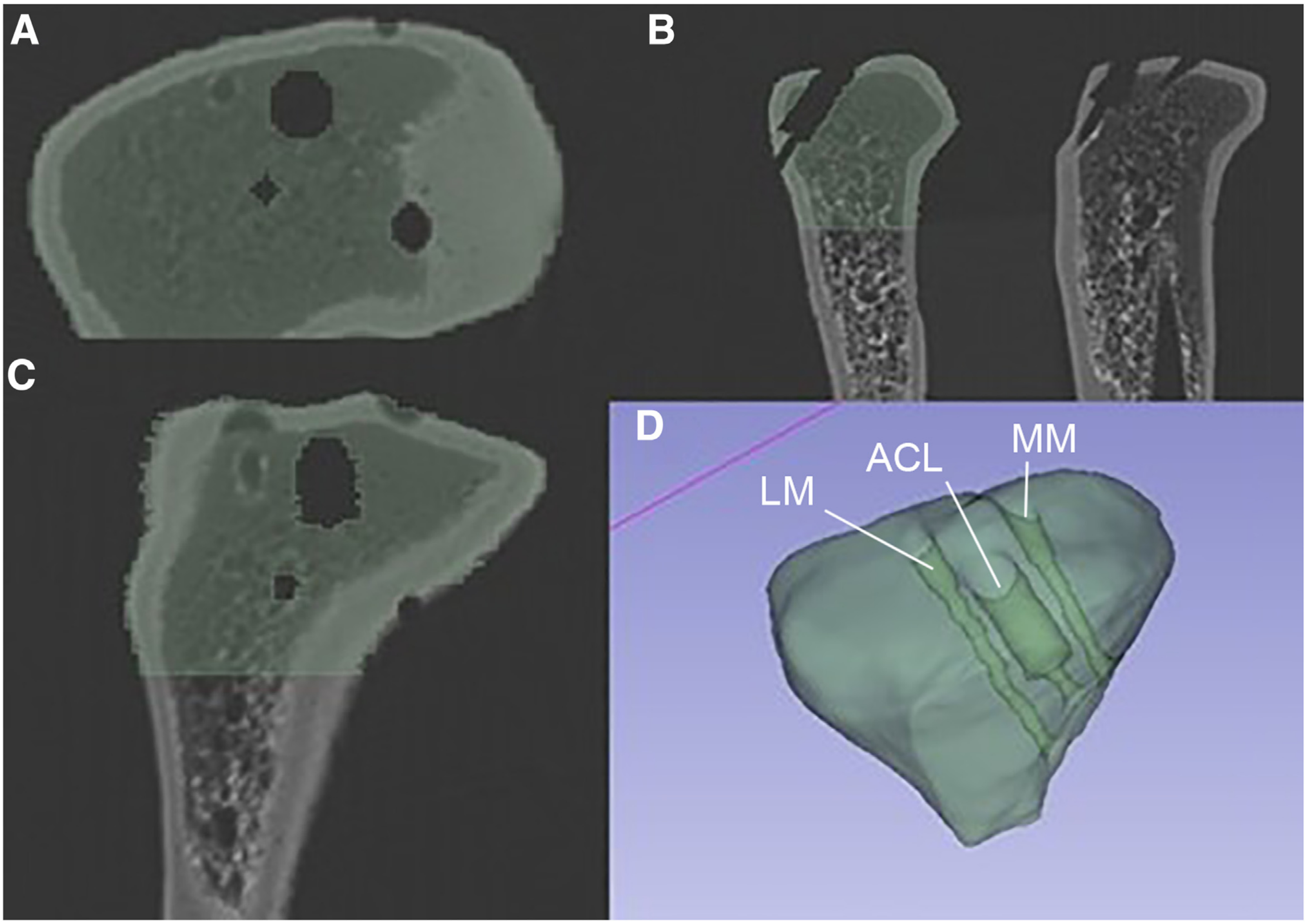

Fig 4. Assessing the risk of tunnel overlap during simultaneous posterior medial or lateral meniscal root repair and ACL reconstruction using 3D CT modeling. CT scans were visualized and first processed using 3D slicer 4.10.2. Each scan was manually refined and evaluated (2D views: [A] axial plane, [B] sagittal plane, and [C] coronal plane) before the 3D models were produced (D). All specimens were right tibia. (2D, 2-dimensional; 3D, 3-dimensional; ACL, anterior cruciate ligament; CT, computed tomography; LM, lateral meniscus; MM, medial meniscus.)

was standardized in terms of positioning, slice number and orientation, and acquisition time.

Each CT scan was sectioned, one slide at a time, in the XY plane using 3D Slicer 4.10.2 (freeware, open source, https://www.slicer.org). 3D Slicer is a multiplatform, free open-source software for visualization and image computing.[30] Each slide was first roughly traced using the "level tracing" feature in 3D Slicer, then manually touched up using the paint and erase tools. Once all slides in a scan were evaluated, a 3D model was produced and then smoothed using the "smoothing" feature (Fig 4). Following the smoothing, the models were exported as .STL files and loaded into Autodesk Meshmixer (free software for working with triangle meshes, http://www.meshmixer.com) for evaluation and touching up. This process was repeated several times for each scan and the greatest quality model for each specimen was selected based on the clarity, accuracy, and consistency of the internal geometry (Fig 5).

Once the model was created, each proximal tibia was separated into individual .STL files using Meshmixer and modeled from 130,000 triangles to 10,000 to 13,000 triangle faces to allow for processing in SolidWorks (SolidWorks Corporation, Waltham, MA). Once the models were loaded into SolidWorks, an .SLDPRT file was generated. The opacity of the model was reduced to 30% to assist in internal evaluation. For each tunnel, entry and exit holes were defined by selecting a triangle face roughly parallel to the apparent plane of the hole and creating a 3-point circle on that plane selecting points on the edge of the hole. Once all holes were defined, reference axes were generated through the center point of each respective pair to create central axis references for each tunnel.

To ensure consistency in tunnel diameter for evaluation, a reference plane was created at the surface of the entry hole normal to the central axis of each tunnel, and a circular extruded cut was made along the axis

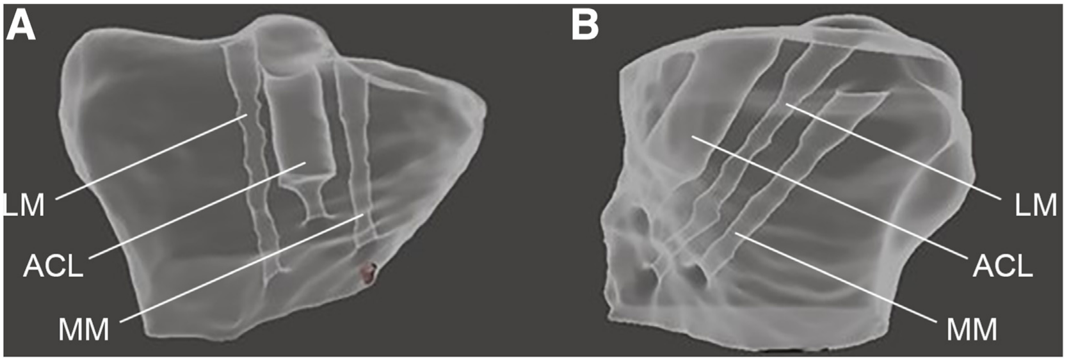

Fig 5. Assessing the risk of tunnel overlap during simultaneous right knee posterior medial or lateral meniscal root repair and ACL reconstruction using 3D CT modeling. Autodesk Meshmixer was used for refinement of the 3D models. (A) Front (coronal) view of the 3D model after refinement with Meshmixer. (B) Lateral (sagittal) view of the same 3D model. (3D, 3-dimensional; ACL, anterior cruciate ligament; CT, computed tomography; LM, lateral meniscus; MM, medial meniscus.)

with the previously measured tunnel diameter and depth. The measured diameters agreed well with the modeled tunnels and most tunnel interior surfaces were only skimmed by the extruded cut. Once all tunnels and axes were defined the distance between individual tunnels was measured using the evaluation tools in SolidWorks (Fig 6). For tunnels whose axes did not cross within the model, the nearest point should be at the articular surface. In those cases, points were manually selected along each respective tunnel and carefully checked to ensure no nearer point existed before the measure tool was used to determine the nearest point distance.

Data Analysis

To test the hypothesis, distances (mean ± standard deviation in millimeters) between the ACL tibial socket-tunnel and each of the meniscus root socket-tunnels were characterized. The variables considered were the distances between the tunnels' central axes (centerline distance, or CD) and the calculated distance for the closest edges between the tunnels (nearest edge distance, or NED). Overlap was defined as a distance smaller than 2 mm between socket-tunnels, as previously reported.[26,31] As there were several data set that failed tests for normality, nonparametric statistical analyses were performed using the Kruskal-Wallis test. Mann-Whitney *U* test was used to compare differences between each 2 independent groups. A *P* value of < .05 was considered as significant difference. Significance values were adjusted by the Bonferroni correction for multiple tests.

Results

The mean (95% confidence interval [CI]), CD, and NED distances between tibial socket-tunnels for ACLR and medial and lateral menisci roots are shown in Table 1. For ACLR and socket-tunnels for the medial meniscus posterior root (ACL-MMPR socket-tunnel distances), no statistically significant differences between the groups were noted. The average CD between tunnels was 19.63 mm (95% CI: 19.23-20.23; range 15.62-22.50 mm) and NED between the tunnels was on average 12.38 mm (95% CI: 11.78-12.98; range 8.37-15.25 mm). No tunnel overlap was observed between ACL tunnels and tunnels for the posterior roots of the medial meniscus.

For ACLR and socket-tunnels for the posterior root of the lateral meniscus (ACL-PRLM socket-tunnel distances), the ACL60RT65 subgroup (ACL tunnel drilled at 60° and posterior root of LM drilled at 65° of angulation) (average CD: 14.10/average NED: 6.59 ± 1.59

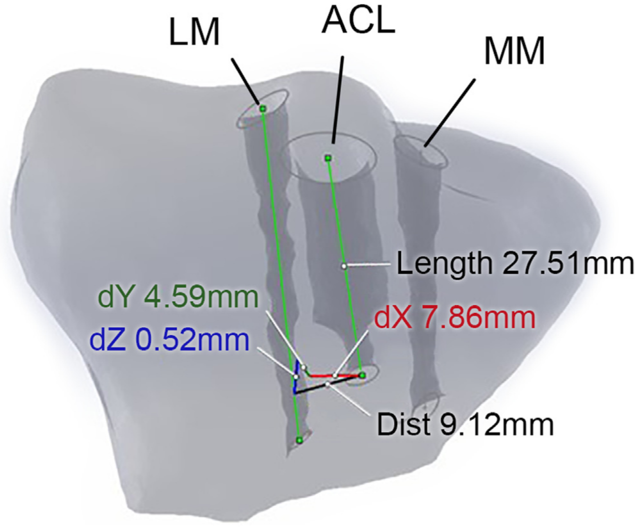

Fig 6. Assessing the risk of tunnel overlap during simultaneous posterior medial or lateral meniscal root repair and ACL reconstruction using 3D CT modeling. All tunnels and axes were defined and the distance between individual tunnels was measured using the evaluation tools in SolidWorks. (3D, 3-dimensional; ACL, anterior cruciate ligament; CT, computed tomography; LM, lateral meniscus; MM, medial meniscus.)

Table 1. Assessing the Risk of Tunnel Overlap During Simultaneous Posterior Medial or Lateral Meniscal Root Repair and ACLR Using 3D CT Modeling

	LMPR Socket-Tunnel				MMPR Socket-Tunnel			
ACLR Socket-Tunnel	55°	60°	65°	*P* Value	55°	60°	65°	*P* Value
Centerline distance (CD)								
55°	14.41 ± 3.66	10.30 ± 1.51	12.38 ± 0.63	.041*	21.05 ± 1.64	19.02 ± 1.43	20.14 ± 1.81	.23 (NSD)
60°	9.03 ± 1.05	11.69 ± 3.45	14.10 ± 1.80		17.57 ± 1.70	20.17 ± 1.81	20.88 ± 1.38	
65°	8.60 ± 2.15	10.78 ± 1.92	12.01 ± 2.94		19.65 ± 0.16	19.86 ± 1.36	18.31 ± 2.92	
Calculated nearest edge distance (NED)								
55°	6.91 ± 3.66	2.80 ± 1.51	4.88 ± 0.63	.041*	13.79 ± 1.64	11.76 ± 1.43	12.89 ± 1.81	.23 (NSD)
60°	1.53 ± 1.05	4.19 ± 3.45	6.59 ± 1.80		10.32 ± 1.70	12.92 ± 1.81	13.63 ± 1.38	
65°	1.10 ± 2.15	3.28 ± 1.92	4.51 ± 2.94		12.40 ± 0.16	12.60 ± 1.36	11.06 ± 2.92	

NOTE. Central axes and nearest edges distances in mm, mean (CI) between ACLR tibial socket-tunnels and socket-tunnels for lateral and medial meniscal posterior roots.

3D, 3-dimensional; ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CI, confidence interval; LMPR, lateral meniscus posterior root; MMPR, medial meniscus posterior root; NSD, no significant differences.

*Statistically significant differences.

mm) had significantly greater distances when compared with the ACL60RT55 (average CD: 9.03/ average NED: 1.53 ± 0.53 mm; $P = .016$) and ACL65RT55 (average CD: 8.60/average NED: 1.10 ± 1.90 mm; $P = .006$). Also, the ACL55RT55 subgroup (average CD: 14.41/average NED: 6.91 ± 3.23 mm) presented significantly greater ACL-PRLM distances when compared with the same subgroups ACL60RT55 and ACL65RT55. Obvious overlap between tunnels for ACL and for the posterior root of the lateral meniscus occurred in 7 subjects (25.9% of the tunnel-sockets drilled for the lateral meniscus). The subgroups ACL55RT55, ACL55RT65, and ACL60RT65 had no sawbones presenting with overlap between tunnels for ACL and the posterior root of lateral meniscus.

Socket-Tunnel Overlap

Using the a priori definition for socket-tunnel overlap of NED <2 mm, overlap occurred in 7 of 81 possible combinations (8.6%), as follows (Table 2): (1) ACLR and posterior root of the lateral meniscus: 7 cases (25.9%) and (2) ACLR and posterior root of the medial meniscus: 0 cases (0%)

Considering the depth from the from the tibial articular surface, most of the socket-tunnel overlap (n = 5/ 7; 71.4%) occurred between sockets at depths ranging between 3.6 and 5.2 mm for the ACLR socket-tunnel (range 1.1-7 mm) and at a depth of 10 mm for all LMPR sockets (100%) with respect to the tibial articular surface. In 1 case, a specimen from subgroups ACL60RT60 (14.3%), the socket overlap occurred at the articular surface of the tibia. For all other sockets, no overlap occurred at the tibial articular surface.

Discussion

The present study found no significant risk of socket-tunnel overlap when drilling for combined ACLR and MMPR repair; however, 7 instances of overlap (25.9%) were encountered with concomitant ACLR and LMPR repair, confirming our hypothesis. In addition, the groups in which ACLR socket-tunnel and the socket-tunnels for the root of the menisci were created with the same drilling parameters did not necessarily limit overlap. Among the subgroups with the same socket-tunnel drill guide inclination, only subgroup ACL55RT55 performed better than the others. Subgroups ACL55RT65 and ACL60RT65 groups had similar results to the ACL55RT55.

Of the cases with socket-tunnel overlap, all occurred between ACLR and socket-tunnels to the LMPR and no cases of overlap occurred between ACLR and socket-tunnels for the MMPR. This is explained by the

Table 2. Assessing the Risk of Tunnel Overlap During Simultaneous Posterior Medial or Lateral Meniscal Root Repair and ACLR Using 3D CT Modeling Subgroups in Which Overlap (Distance <2 mm) Between Socket-Tunnels Occurred Is Demonstrated

Socket-Tunnels Overlapping	Subgroups (n = 3/Subgroup)
ACL-LMPR	ACL55RT60*
7/27 cases of overlap (= 25.9%)	ACL60RT55†
	ACL60RT60*
	ACL65RT55*
	ACL65RT60*
	ACL65RT65*
ACL-MMPR	No overlap
0/27 cases of overlap	

NOTE. Seven of 27 lateral meniscal specimens (25.9%) presented overlapping tunnels. All cases of overlap (100%) occurred between the ACL tunnel and the tunnel for the LMPR.

3D, 3-dimensional; ACL, anterior cruciate ligament; ACLR, anterior cruciate ligament reconstruction; CT, computed tomography; LMPR, lateral meniscus posterior root; MMPR, medial meniscus posterior root; RT, meniscal root.

*Subgroups having one specimen in which overlap occurred.

†Subgroup having two specimens in which cases of overlap occurred.

greater anatomical proximity of the ACL to the lateral meniscus, when compared with the medial meniscus.[13,32] In addition, lower levels of inclination (55° or 60°) correlated to increased potential for overlap. Finally, as all tunnels in this study were performed on the anteromedial tibia, the high density of tunnels in the same anatomic region increased the risk of communication between tunnels. This is clinically relevant, as the margin for error (tunnel convergence) is therefore significantly lower when performing a concomitant lateral meniscal root repair. Clinically, converging tunnels will not affect ACL or meniscal healing but can cause the passing or repair sutures for either repair to be damaged which would affect quality of the repair/reconstruction.

Gursoy et al.[26] had similar findings in their study to examine the risk of tunnel overlap in the setting of both ACL and PCL reconstructions performed in conjunction with posterior medial and lateral menisci root repairs. However, these authors used imaging from 20 specimens who did not undergo actual tunnel creation for meniscal repair and ACL reconstruction. Instead, they used an image processing software to perform "virtual tunnel drilling" (to simulate tunnel creation) and virtually measure tunnel convergence. Despite that, they showed that all specimens (100%) presented overlap between the ACL and the tunnel for the posterior root of the lateral meniscus when they used current standard for creating the tunnels. However, when they used a more distal entry point for the lateral meniscus tunnels and reoriented them to be parallel to the 65° ACL tibial tunnel, they had no cases of tunnel overlap.[26] This study also used 3.5-mm tunnels comparted with 6mm sockets used in the present study. Minimizing tunnel-socket diameter is a possible strategy that can be used to decrease convergence and increase the size of the bone bridge between tunnels.[33]

Another option to minimize the risk of socket-tunnel convergence would be to use a meniscal repair technique that does not involve creating tibial tunnels.[34] There are several techniques described for repairing the posterior root of the meniscus and they can be divided into transtibial pull-out repair and anchor repair techniques. We used meniscal repair with the transtibial technique in this study, given is it commonly performed, and our purpose was to assess a technique for combined meniscal root repair and ACLR that best replicate the authors current surgical technique. Several techniques can be used to minimize convergence between the ACL and lateral meniscal root tunnel. Meniscal root repair techniques using anchors are an alternative option to avoid creating additional tunnels in the tibia and to minimize the risk of convergence between them. However, these techniques require the creation of a posteromedial or posterolateral portal and can be technically demanding. Generally, for meniscal fixation with an anchor to be possible, it is necessary to flex the knee in such a way that the arthroscopic view of the ideal anchor placement point is compromised, which demands a steep learning curve on the part of the surgeon, in addition to the risk of articular cartilage injury, neurovascular injury, and nonanatomical fixation of the meniscus.[13,14,35,36] Alternatively lateral meniscus posterior root fixation could occur lateral to the tibial tubercle. Although this is a described and accepted technique, the authors avoid this, when possible, to decrease trauma to the anterior compartment as well as due to the difficult nature of obtaining fixation on the lateral tibial surface.

Limitations

This study is not without limitation. First, all surgical procedures in our study were performed by a single surgeon, which both represents a limitation and a strength. Tunnel placement was largely left to the discretion of the single surgeon, which could influence bias; however, this also recreates reproducibility, as any error or bias was likely to be replicated by this single surgeon. Alterations in hand placement by the surgeon could alter overall ACL guide position, despite consistent guide angles, and therefore affect the results. To minimize error, 3 specimens per ACL-meniscal guide combination were used, and rigid ACL guides were used to minimize potential guide placement variability. Despite this sample size, no power analysis was done and there exists a potential for type II error. Another limitation was the use of sawbones for the procedures when human specimens would be preferred to best mimic real anatomy and clinical data more accurately. Sawbones have the advantage of ease of availability and less cost and also consistency, as all of the models had the same anatomy with regards to tibial size and slope, as well as the anatomy of the tibial plateau and tibial spines. In addition, the angulation of the tunnels was standardized only in relation to one plane (tibial articular surface) and these tunnels have an obvious 3D configuration. Although a limitation, this most replicates true surgical conditions as this is the same rigid ACL guide used in the operating room. Lastly, the modeling software has potential for not perfectly modeling the tunnels and sockets, which could cause issues with measurement. For this reason, 3 specimens were assigned per group to help limit this as a potential source of error.

Conclusions

This study demonstrated 25.9% rate of overlap for combined LMPR repair and ACLR, compared with 0% for MMPR repair with ACLR. Lower ACL drilling angle

(55 or 60°) combined with greater lateral meniscus drilling angle (65°) produced no socket-tunnel overlap.

Disclosures

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References

1. Choi CJ, Choi YJ, Lee JJ, Choi CH. Magnetic resonance imaging evidence of meniscal extrusion in medial meniscus posterior root tear. *Arthroscopy* 2010;26:1602-1606.
2. Koenig JH, Ranawat AS, Umans HR, Difelice GS. Meniscal root tears: Diagnosis and treatment. *Arthroscopy* 2009;25:1025-1032.
3. Spang JT, Dang ABC, Mazzocca A, et al. The effect of medial meniscectomy and meniscal allograft transplantation on knee and anterior cruciate ligament biomechanics. *Arthroscopy* 2010;26:192-201.
4. Chen L, Linde-Rosen M, Hwang SC, et al. The effect of medial meniscal horn injury on knee stability. *Knee Surg Sports Traumatol Arthrosc* 2015;23:126-131.
5. Lee SR, Kim JG, Nam SW. The tips and pitfalls of meniscus allograft transplantation. *Knee Surg Relat Res* 2012;24:137-145.
6. Rijk PC. Meniscal allograft transplantation—part I: Background, results, graft selection and preservation, and surgical considerations. *Arthroscopy* 2004;20:728-743.
7. Ahn JH, Bae TS, Kang KS, Kang SY, Lee SH. Longitudinal tear of the medial meniscus posterior horn in the anterior cruciate ligament-deficient knee significantly influences anterior stability. *Am J Sports Med* 2011;39:2187-2193.
8. Gupta R, Kapoor A, Mittal N, Soni A, Khatri S, Masih GD. The role of meniscal tears and meniscectomy in the mechanical stability of the anterior cruciate ligament deficient knee. *Knee* 2018;25:1051-1056.
9. Rodeo SA. Meniscal allografts—where do we stand? *Am J Sports Med* 2001;29:246-261.
10. Padalecki JR, Jansson KS, Smith SD, et al. Biomechanical consequences of a complete radial tear adjacent to the medial meniscus posterior root attachment site: In situ pull-out repair restores derangement of joint mechanics. *Am J Sports Med* 2014;42:699-707.
11. Allaire R, Muriuki M, Gilbertson L, Harner CD. Biomechanical consequences of a tear of the posterior root of the medial meniscus. Similar to total meniscectomy. *J Bone Joint Surg Am* 2008;90:1922-1931.
12. Pache S, Aman ZS, Kennedy M, et al. Meniscal root tears: Current concepts review. *Arch Bone Jt Surg* 2018;6:250-259.
13. Krych AJ, Hevesi M, Leland DP, Stuart MJ. Meniscal Root Injuries. *J Am Acad Orthop Surg* 2020;28:491-499.
14. Moatshe G, Chahla J, Slette E, Engebretsen L, Laprade RF. Posterior meniscal root injuries. *Acta Orthop* 2016;87:452-458.
15. Beaufils P, Pujol N. Management of traumatic meniscal tear and degenerative meniscal lesions. Save the meniscus. *Orthop Traumatol Surg Res* 2017;103:S237-S244.
16. Chahla J, LaPrade RF. Meniscal root tears. *Arthroscopy* 2019;35:1304-1305.
17. Kim JG, Lee YS, Bae TS, et al. Tibiofemoral contact mechanics following posterior root of medial meniscus tear, repair, meniscectomy, and allograft transplantation. *Knee Surg Sports Traumatol Arthrosc* 2013;21:2121-2125.
18. Rueff D, Nyland J, Kocabey Y, Chang HC, Caborn DNM. Self-reported patient outcomes at a minimum of 5 years after allograft anterior cruciate ligament reconstruction

with or without medial meniscus transplantation: An age-, sex-, and activity level-matched comparison in patients aged approximately 50 years. *Arthroscopy* 2006;22: 1053-1062.
19. Seon JK, Gadikota HR, Kozanek M, Oh LS, Gill TJ, Li G. The effect of anterior cruciate ligament reconstruction on kinematics of the knee with combined anterior cruciate ligament injury and subtotal medial meniscectomy: An in vitro robotic investigation. *Arthroscopy* 2009;25:123-130.
20. Neyret P, Donell ST, Dejour H. Results of partial meniscectomy related to the state of the anterior cruciate ligament. Review at 20 to 35 years. *J Bone Joint Surg Br* 1993;75:36-40.
21. Papageorgiou CD, Gil JE, Kanamori A, Fenwick JA, Woo SL, Fu FH. The biomechanical interdependence between the anterior cruciate ligament replacement graft and the medial meniscus. *Am J Sports Med* 2001;29:226-231.
22. Mehl J, Otto A, Baldino JB, et al. The ACL-deficient knee and the prevalence of meniscus and cartilage lesions: A systematic review and meta-analysis (CRD42017076897). *Arch Orthop Trauma Surg* 2019;139:819-841.
23. Bozkurt M, Tahta M, Akkaya M, Isik C, Gursoy S. Good clinical results can be obtained along with reduced risk of tunnel communication with a new technique in concomitant meniscus transplantation and ACL reconstruction. *Knee Surg Sports Traumatol Arthrosc* 2018;26:622-627.
24. Zhang YD, Hou SX, Zhang YC, Luo DZ, Zhong HB, Zhang H. Arthroscopic combined medial and lateral meniscus transplantation after double-tunnel, double-bundle anterior cruciate ligament reconstruction in the same knee. *Knee* 2012;19:953-958.
25. Cook JL, Cook CR, Bozynski CC, Bezold WA, Stannard JP. Development and assessment of novel multiligament knee injury reconstruction graft constructs and techniques. *J Knee Surg* 2022;35:456-465.
26. Gursoy S, Perry AK, Brady A, et al. Optimal tibial tunnel placement for medial and lateral meniscus root repair on the anteromedial tibia in the setting of anterior and posterior cruciate ligament reconstruction of the knee. *Am J Sports Med* 2022;50:1237-1244.
27. Kennedy MI, Strauss M, LaPrade RF. Injury of the meniscus root. *Clin Sports Med* 2020;39:57-68.
28. Cerulli G, Zamarra G, Vercillo F, Pelosi F. ACL reconstruction with “the original all-inside technique.”. *Knee Surg Sports Traumatol Arthrosc* 2011;19:829-831.
29. Nuelle CW, Balldin BC, Slone HS. All-inside anterior cruciate ligament reconstruction. *Arthroscopy* 2022;38: 2368-2369.
30. Fedorov A, Beichel R, Kalpathy-Cramer J, et al. 3D Slicer as an image computing platform for the Quantitative Imaging Network. *Magn Reson Imaging* 2012;30: 1323-1341.
31. Moatshe G, Slette EL, Engebretsen L, LaPrade RF. Intertunnel relationships in the tibia during reconstruction of multiple knee ligaments: How to avoid tunnel convergence. *Am J Sports Med* 2016;44:2864-2869.
32. Sundararajan SR, Ramakanth R, Rajasekaran S. Meniscal root repair along with auxiliary procedures for joint preservation: Current concepts. *Indian J Orthop* 2021;55: 237-251.
33. Zhou Y, Bai F, Liu X, She H, Ding C, Xiang B. Shared ACL bone tunnel technique for repair of lateral meniscus posterior root tears combined with ACL reconstruction. *Orthop J Sports Med* 2022;10:23259671221114319.
34. Choi NH, Son KM, Yoo SY, Victoroff BN. Femoral tunnel widening after hamstring anterior cruciate ligament reconstruction with bioabsorbable transfix. *Am J Sports Med* 2012;40:383-387.
35. Lee SK, Yang BS, Park BM, Yeom JU, Kim JH, Yu JS. Medial meniscal root repair using curved guide and soft suture anchor. *Clin Orthop Surg* 2018;10:111-115.
36. Eun SS, Lee SH, Sabal LA. Arthroscopic repair of the posterior root of the medial meniscus using knotless suture anchor: A technical note. *Knee* 2016;23:740-743.