

# ACL Beyond the Ligament

## Increased Posterior Tibial Slope is Associated with Revision ACL Graft Re-Rupture

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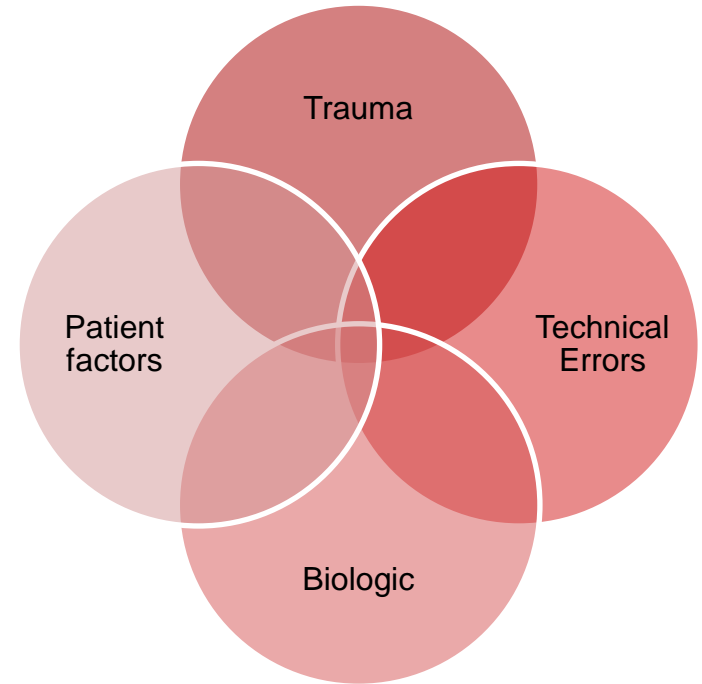
# Disclosures

- Robert A. Duerr, MD
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- Benjamin Ormseth, BS
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- Alex Dibartola, MD
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- David Flanigan, MD
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# Background

## *ACL Graft Failures*

- Anterior cruciate ligament (ACL) failures occur in up to 25% of young patients in high risk activities (Wiggins AJSM 2016)
- Cause is often multifactorial
- Increased interest in anatomic factors
  - Sagittal inclination of tibial plateau
  - Posterior tibial slope (PTS)



# Background

## *Posterior Tibial Slope*

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- Biomechanical studies → increased PTS associated with increased anterior tibial translation and ACL strain
  - Giffin et al. AJSM 2004, Bernhardson et al. AJSM 2019
- PTS elevated in patients with ACL injury versus un-injured controls in meta-analysis of 29 studies
  - Wang et al. Arthroscopy 2017
- PTS elevated in patients with multiple ACL failures
  - Grassi et al. AJSM 2019, Winkler et al. KSSTA 2021
- Slope-reducing osteotomy may be considered in patients with multiple ACL graft failures and  $PTS \geq 12^\circ$ 
  - Dejour et al. KSSTA 2015

# Purpose

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- To compare PTS on both lateral knee radiographs and MRI in patients who experience revision ACL graft failure versus age-, sex-, and graft matched controls
- Identify cutoff values for PTS measurements that predict risk of revision ACL failure

# Hypothesis

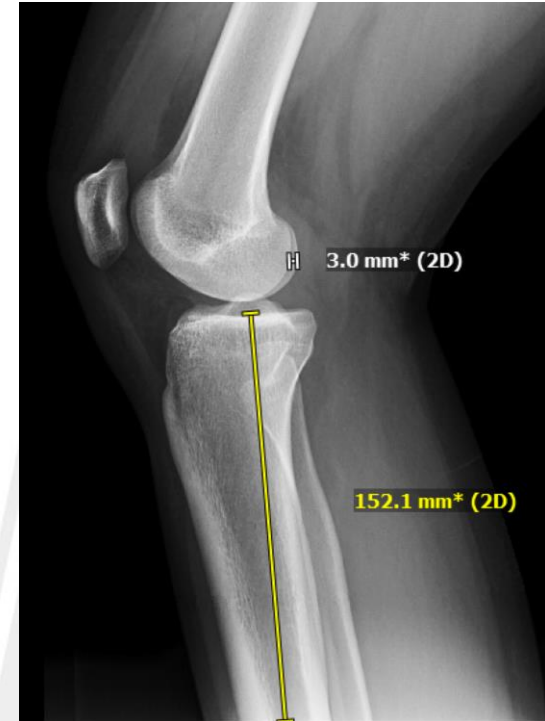
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- Patients who experienced revision ACL graft failure would exhibit elevated (steeper) PTS compared to patients with successful revision ACL on both lateral knee radiographs and MRI
- $PTS \geq 12^\circ$  on lateral knee radiographs would be a predictive risk factor for revision ACL re-tear

# Methods

- Retrospective review of Revision ACL clinical database
- Inclusion criteria:
  - Failure of revision graft
    - Re-revision ACLR or clinical exam and MRI evidence of re-tear
  - Acceptable lateral knee radiographs and MRI
- Exclusion:
  - Multi-ligament injury, previous fracture of tibia, previous knee infection or failure due to infection
- Matched 1:1 by age (+/- 5 years), sex, and revision graft type to control patients with minimum 2 years follow-up

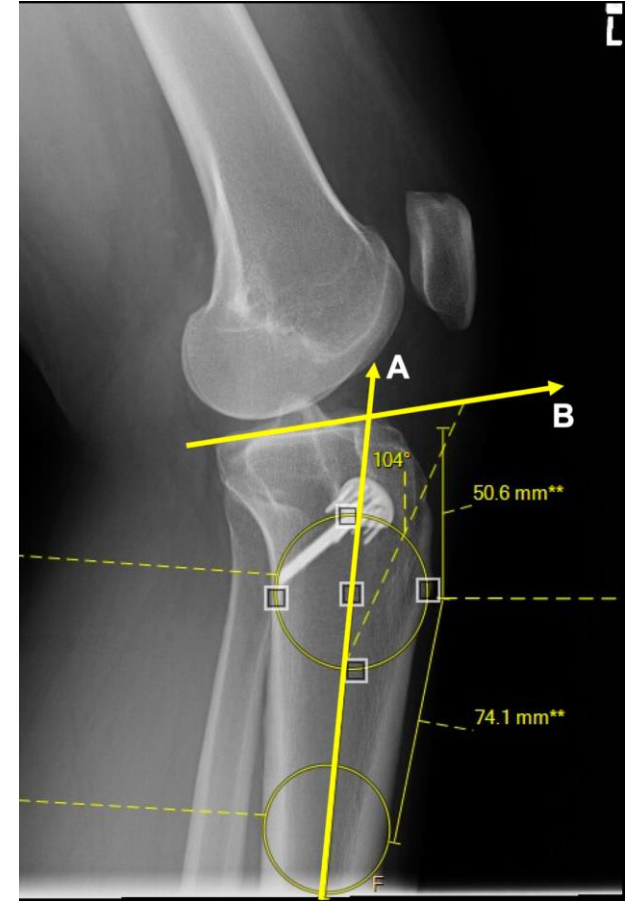
Acceptable radiograph



# Methods

## *PTS XR Measurements*

- Tibial anatomic axis defined as midpoint 5 cm below joint line and lowest visualized portion
- Angle formed with tangent of Medial and Lateral tibial plateau

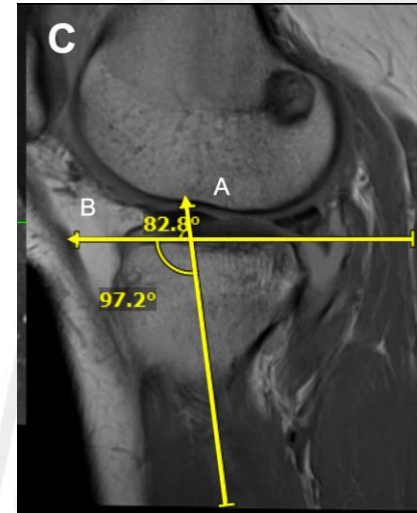
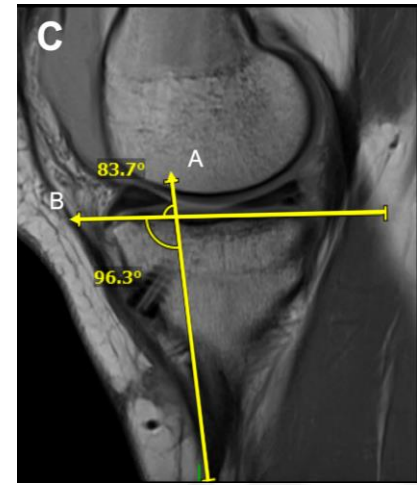
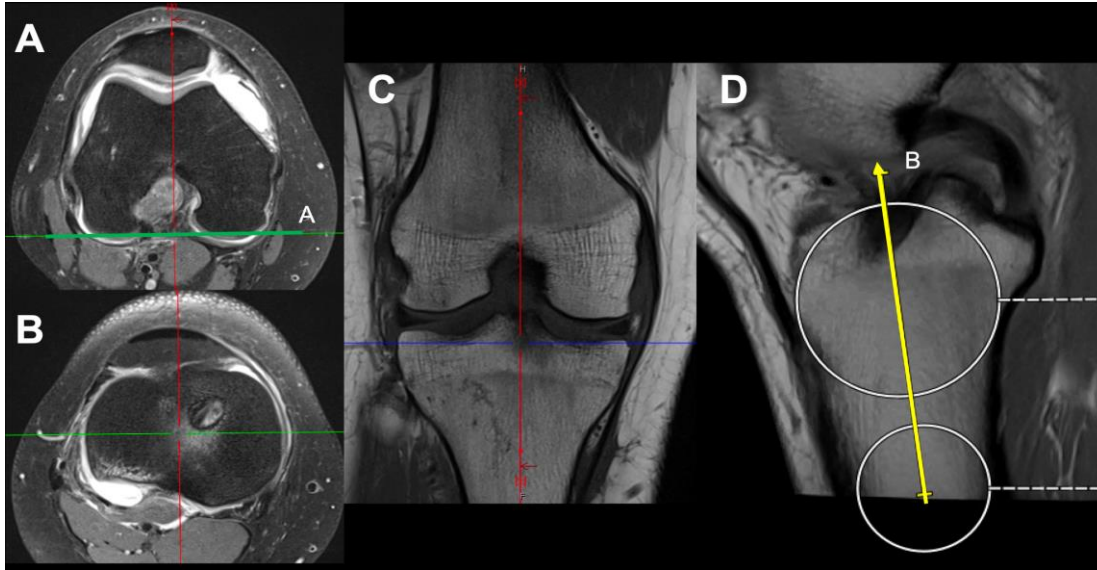




# Methods

## *PTS MRI Measurements*

- Hashemi et al method (JBJS 2008)



# Methods

## *Statistical Analysis*

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- Power analysis: 3° difference on X-ray with a standard deviation of 3° → 17 patients per group to achieve power >0.85 with alpha 0.05
- Data checked for normality using Kolmogorov-Smirnov test
- Independent samples t-tests used to compare medial and lateral PTS between cases and controls
- Optimal cutoff values for predicting increased risk of revision ACL failure determined by receiver operating characteristic (ROC) curves
  - Youden index calculated to select cutoff with highest Sens & Spec
- Conditional multi-variable logistic regression used to assess relative contributions of PTS cutoff values as predictors of revision ACL failure

# Results

	Cases (n = 38)	Controls (n = 38)
Age (yr)	24.0 +/- 6.7	23.8 +/- 6.6
BMI (kg/m <sup>2</sup> )	28.2 +/- 5.5	28.3 +/- 6.0
Male/Female	23/15	23/15
Revision Graft type		
BTB Auto	1	1
Hamstring Auto	15	15
Soft tissue allo	18	17
Hybrid	4	5
Partial medial meniscectomy	13 (34%)	16 (42%)
Partial lateral meniscectomy	12 (32%)	20 (53%)
Time to re-tear/Follow-up (yr)	4.1 +/- 3.1	6.2 +/- 2.9

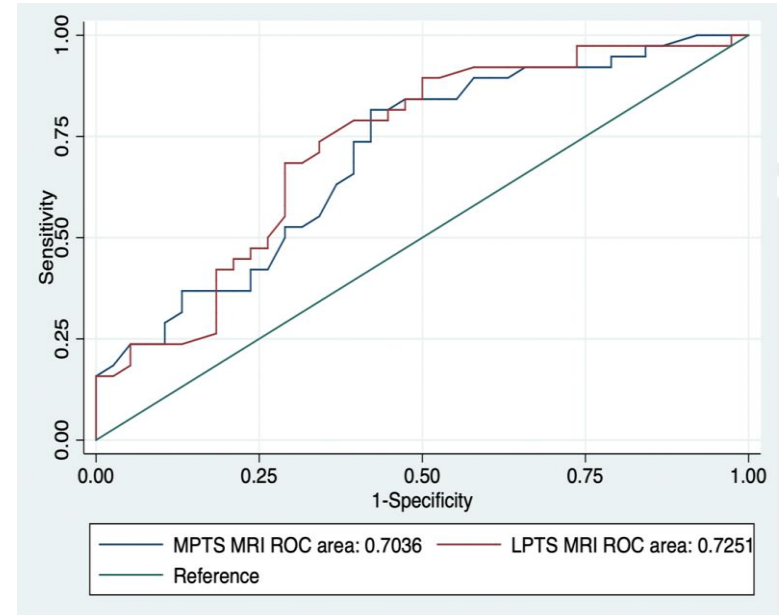
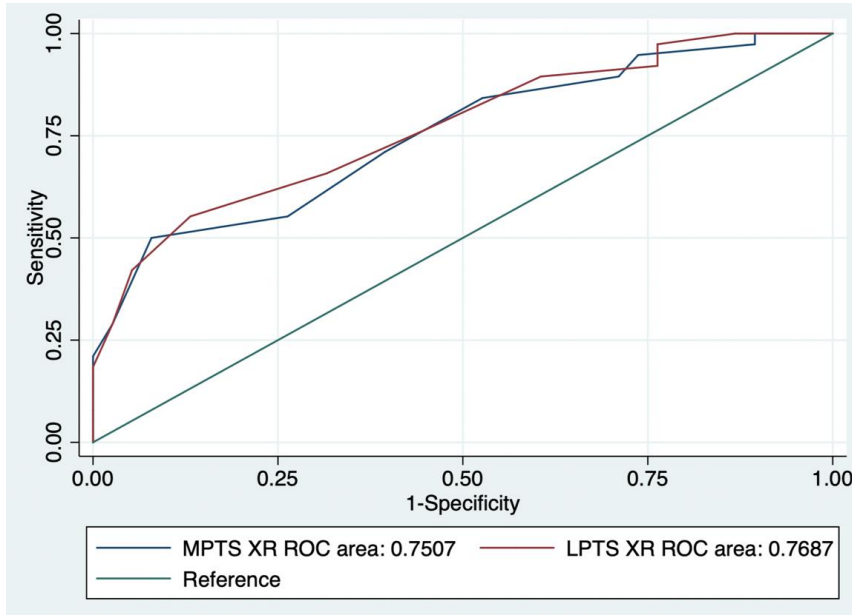
# Results

Posterior Tibial Slope Measurements <sup>a</sup>			
	Cases (n = 38)	Controls (n = 38)	Significance
MRI			
Medial PTS	7.2 ± 3.1	4.8 ± 2.9	p < 0.001
Lateral PTS	8.4 ± 3.1	5.9 ± 3.0	p < 0.001
Radiograph			
Medial PTS	13.2 ± 2.9	10.3 ± 2.9	p < 0.001
Lateral PTS	12.9 ± 3.0	9.8 ± 2.8	p < 0.001

<sup>a</sup>Values presented as mean ± SD.

# Results

## Receiver Operating Characteristic Curves



# Results

## Receiving Operator Characteristics Analyses

	Cutoff	Cases	Controls	Sensitivity	Specificity	Youden Index	AUC <sup>α</sup>
<b>MRI</b>							
<b>Medial PTS</b>	≥5°	31	16	81.6%	57.9%	0.395	0.704 ± 0.06 [0.586-0.821]
<b>Lateral PTS</b>	>6.5°	28	13	73.7%	65.8%	0.395	0.725 ± 0.06 [0.609-0.841]
<b>Radiograph</b>							
<b>Medial PTS</b>	≥14°	19	3	50.0%	92.1%	0.421	0.751 ± 0.06 [0.643-0.859]
<b>Lateral PTS</b>	≥13°	21	5	55.3%	86.8%	0.421	0.769 ± 0.05 [0.664-0.873]

<sup>α</sup>Values presented as AUC ± SD [95% CI].

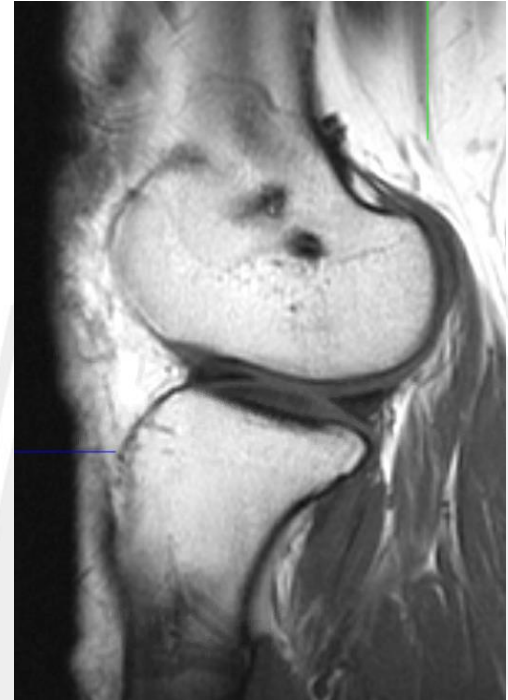
# Results

## Results of Conditional Multi-variable Logistic Regression Analysis

	Cutoff	No.	Odds Ratio	95% CI	P Value
<b>MRI</b>					
<b>Medial PTS</b>	$\geq 5^\circ$	47	2.88	1.0 – 9.1	0.05
<b>Lateral PTS</b>	$\geq 6.5^\circ$	41	4.06	1.2 – 13.5	0.02
<b>Radiograph</b>					
<b>Medial PTS</b>	$\geq 14^\circ$	22	18.71	2.0 – 174.9	0.01
<b>Lateral PTS</b>	$\geq 13^\circ$	26	17.14	1.95 – 150.2	0.01

# Discussion

- All measures of PTS (MRI and radiographs) demonstrated significantly elevated PTS in revision failures versus controls
- Patients with radiographic medial PTS  $\geq 14^\circ$  had 18-times greater odds of revision ACL failure
  - 19/22 (86%) of patients with medial PTS  $\geq 14^\circ$  failed





# Limitations

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- Retrospective study design
  - Unable to control other potential confounding factors for ACL graft failure – pre-injury activity level, ACL tunnel position, amount of meniscus removed at meniscectomy
  - Lack of objective clinical and arthrometric evaluation of laxity
- Control patients may still experience ACL graft failure, though mean follow-up 6.2 years
- Measurement of PTS
  - XR – highly dependent on image rotation, observer experience
  - MRI – difficulty defining tibial anatomic axis

# Conclusions

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- Patients with radiographic medial PTS  $\geq 14^\circ$  or lateral PTS  $\geq 13^\circ$  at increased risk for revision ACL failure
- Patients with MRI medial PTS  $\geq 5^\circ$  or lateral PTS  $\geq 6.5^\circ$  at increased risk for revision ACL failure
- Improve understanding of risk factors for revision ACL graft failure and consider indications for slope-reducing tibial osteotomy

# Thank You

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- [Robert.duerr@osumc.edu](mailto:Robert.duerr@osumc.edu)

# Citations

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