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The Three-Dimensional Osseous Knee Shape is an Accurate Reference for the Native Femoral and Tibial Attachment Sites of the Anterior and Posterior Cruciate Ligaments

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Background

- Accurate identification of native cruciate ligament insertion sites is required to settle the correct tunnel position during reconstruction or appraise tunnel positioning after reconstruction.
- The ability to determine these insertion sites might be challenged by considerable variation in reported location and size of the ligament footprints.
- The three-dimensional osseous morphology varies per person and affects the position of the cruciate ligament insertions.

Purpose

- The aim of this study is to determine the localization of the femoral and tibial native insertion sites of the cruciate ligaments while adjusting for variations in three-dimensional bone geometry.



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Methods

- Statistical shape models (SSMs) of both the distal femur and proximal tibia were created based on segmentations of 103 MR images of knees without signs of osteoarthritis (KL grade 0).
- CT scans of ten lower leg specimens with marked cruciate ligament insertion sites were performed.
- The SSMs were fitted on segmentations of the CT images.
- The segmented cruciate ligament attachment sites of each specimen were addressed to define the ligament attachments on the SSMs.

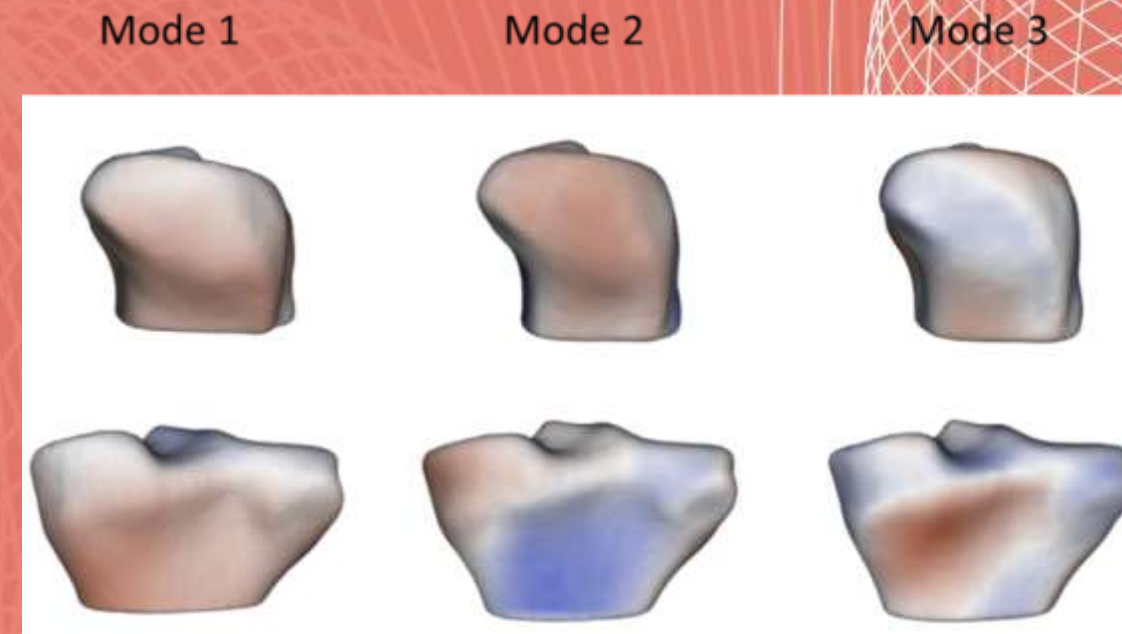
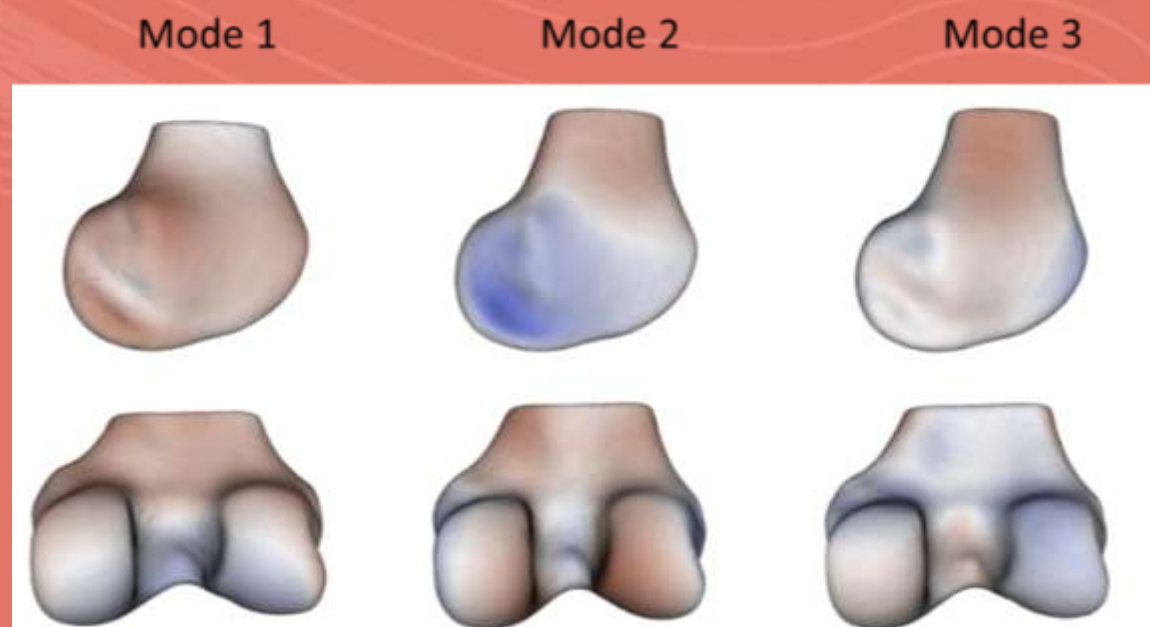


Results (1) – the SSMs

- The SSMs of both the distal femur and proximal tibia each consisted of 4296 correspondence points placed in space as to represent the three-dimensional bony knee shape.
- The quantitative evaluation showed both SSMs were compact, and errors for specificity and generalization for both SSMs remained below 1 mm.
- The modes of variation of the SSMs were able to truthfully depict the three-dimensional osseous shape variations of the distal femur and proximal tibia.

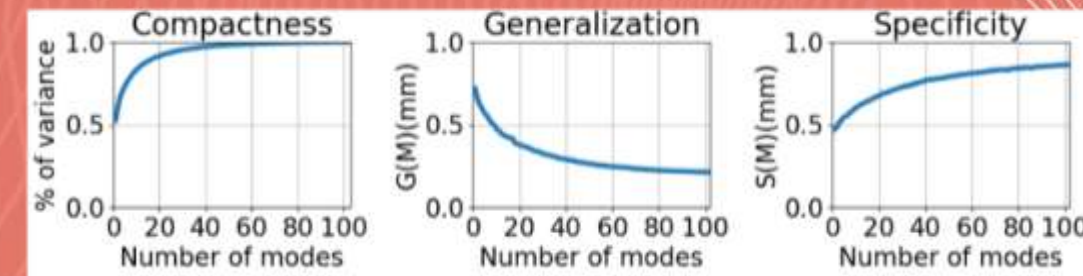
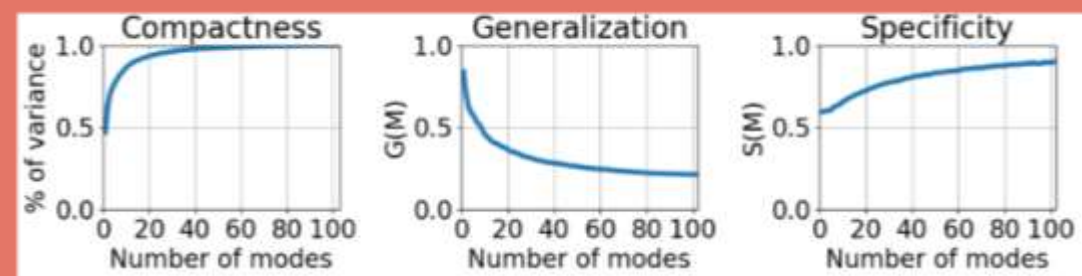


Results (1) – the SSMs



First 3 modes of variation of the SSMs

Modes shown at -2SD; red = inward and blue = outward when moving to +2SD



Quantitative evaluation of both SSMs

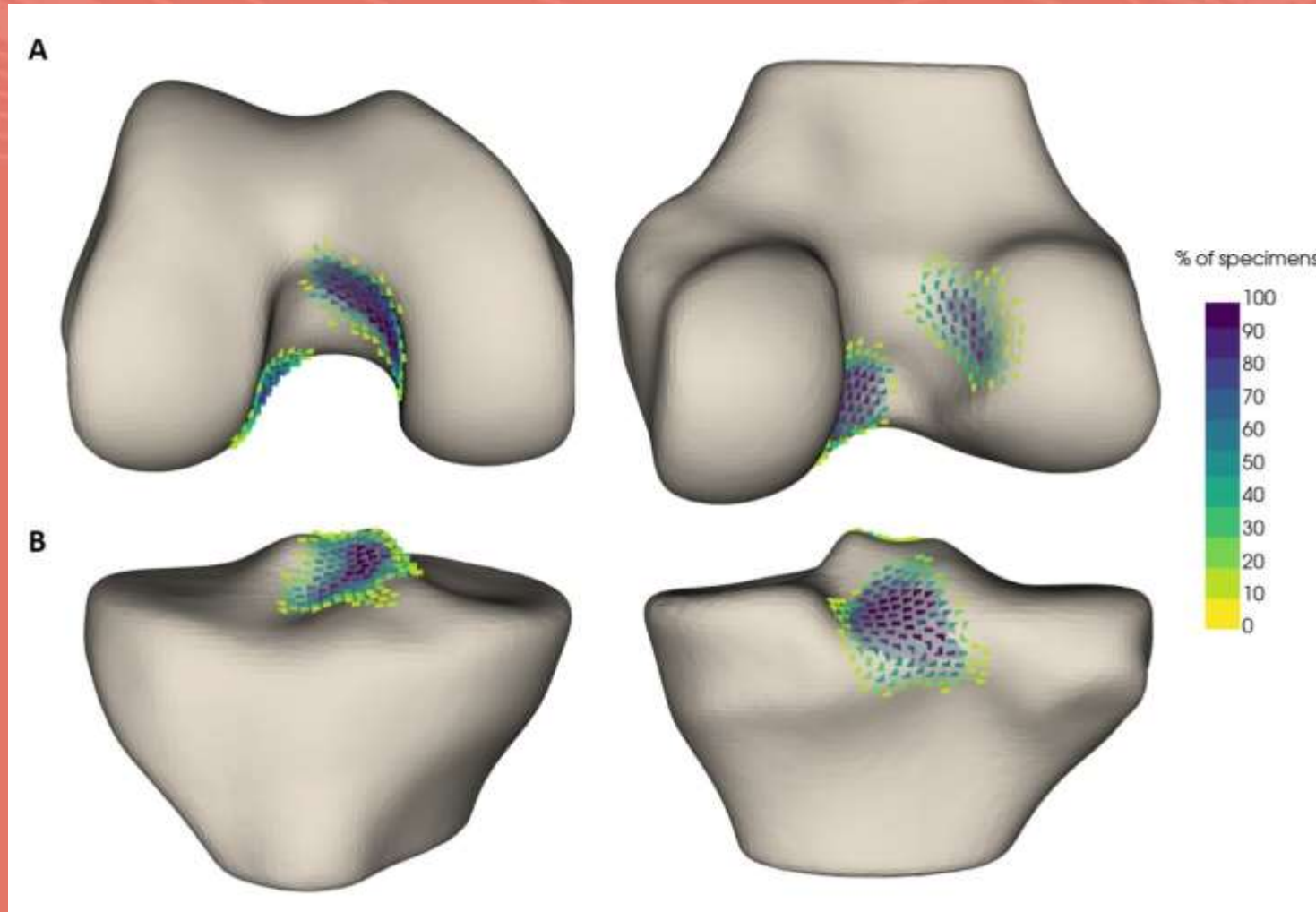


Results (2) – the ACL and PCL insertions on the SSMs

- The ligament attachment sites projected from the segmented specimens onto the fitted SSM shapes indicated a small range of correspondence points as respectively ACL and PCL insertion.
- This indicates the small variation of insertion sites after adjustment for three-dimensional bony geometry
- The femoral attachments of cruciate ligaments have an even more constant attachment site than the tibial attachments.



Results (2) – the ACL and PCL insertions on the SSMs



*small variation of insertion sites
after adjustment for three-
dimensional bony geometry*



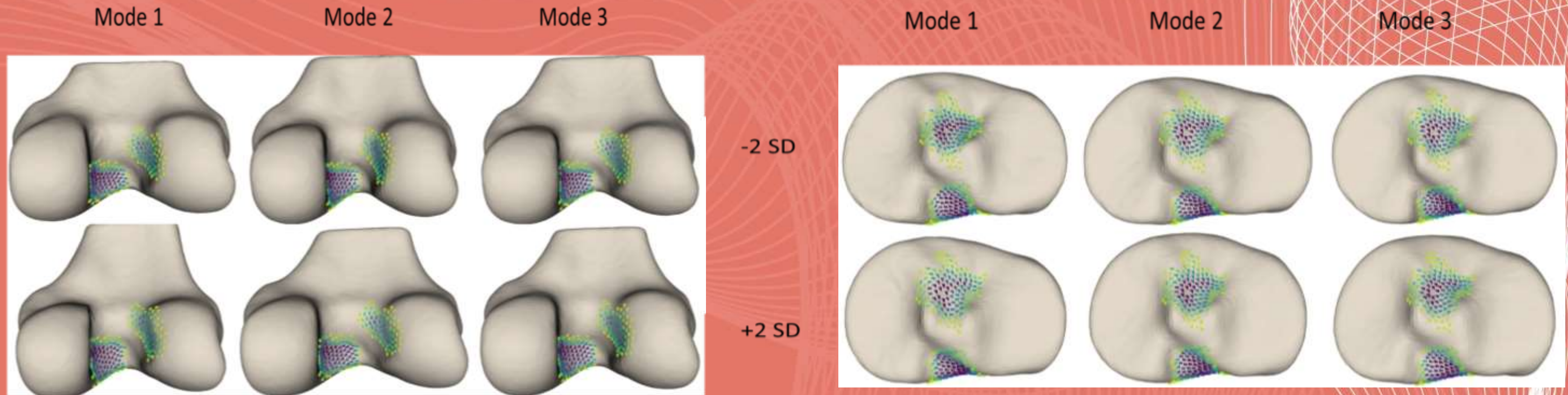
*Scan for an interactive 360°
view of the mean SSMs*

Results (3) – variation of ACL and PCL insertions

- The correspondence points on the SSMs defined as the insertions adapted position and distance towards each other with the different modes of variation.
- Thus, along with the SSMs' modes of variation, these areas defined as ligament insertions varied in location, shape and size.
- This reflects the claimed variation of the ACL and PCL insertions on bony surfaces.



Results (3) – variation of ACL and PCL insertions



The -2SD and +2SD shape of the first 3 modes of variation of the SSMs, including the adaption of areas defined as ACL and PCL attachments

variation of ACL and PCL insertions is a reflection of osseous geometry

Conclusion (1)

- The presumed variation of the attachment sites of cruciate ligaments is only minimal after adjustment for three-dimensional osseous morphology.
- Therefore, it is feasible the three-dimensional osseous geometry of the distal femur and proximal tibia considerably determines the insertion sites of the cruciate ligaments.



Conclusion (2)

- Identifying the ligament attachment sites by referencing to the three-dimensional bony morphology may be a more reliable and better reproducible method, than referencing to landmarks which may have a variable relation to the insertion sites.
- The three-dimensional SSM of either the proximal tibia or the distal femur might be used as template when planning ACL or PCL reconstruction, or when assessing tunnel position after surgery.

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