1. ABOUT THE DATASET

Title: Three subject-specific human tibiofemoral joint finite element models: complete three-dimensional imaging (CT & MR), experimental validation and modelling dataset.

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Rights-holder: University of Leeds

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Description:

This dataset includes the experimental data, three-dimensional imaging, computational models and study data from work validating three subject-specific human tibiofemoral joint finite element models. This work forms part of a wider project developing in vitro and in silico pre-clinical testing methods for tissue preserving treatments of the knee joint.

The aim of the related study was to provide validation of contact mechanics outputs for specimen-specific tibiofemoral joint models and specifically investigate the need for subject-specific shape representation for the cartilage and meniscus tissues.

The dataset provides a complete set of imaging, experimental and computational data for replication of the study. To maximum the potential for re-use the dataset includes imaging and experimental data, which was collected alongside the immediate study data, but not used in that work.

Magnetic resonance imaging of the knee joints in their intact state is included, using eight different imaging sequences. Micro computed tomography imaging of the distal femur and proximal tibia after dissection and testing are also provided for all three knee joints. The experimental data includes pressure sensor measurements taken from the tibial cartilage surface at multiple knee joint flexion angles and photographs taken during dissection, potting and loading of the joints. The computational models are provided for all cases performed for the validation and sensitivity testing study, along with the associated results.

Cite as:

Cooper RJ, Day GA, Wijayathunga VN, Yao J, Mengoni M, Wilcox RK, Jones AC (2023) 'Three subject-specific human tibiofemoral joint finite element models: complete three-dimensional imaging (CT & MR), experimental validation and modelling dataset.' University of Leeds. [Dataset] https://doi.org/10.5518/981

Related publications:

Robert J. Cooper, Gavin A. Day, Vithanage N. Wijayathunga, Jiacheng Yao, Marlène Mengoni, Ruth K. Wilcox, Alison C. Jones. 'Human tibiofemoral joint finite element model validation study: effect of cartilage thickness variation and assessment of precision' (In preparation).

Robert J. Cooper, Aiqin Liu, Gavin A. Day, Vithanage N. Wijayathunga, Louise M. Jennings, Ruth K. Wilcox, Alison C. Jones. 'Development of robust finite element models of porcine tibiofemoral joints loaded under varied flexion angles and tibial freedoms' Journal of the Mechanical Behavior of Biomedical Materials, 2020, 109:103797.

Ethical approval:

Ethical approval was obtained via East Midlands - Leicester South Research Ethics Committee (18/EM/0224)) for the use of fresh-frozen human cadaveric knees in this work.

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Collection:

This dataset belongs to the wider collection entitled "The Institute of Medical and Biological Engineering Knee Dataset", https://doi.org/10.5518/826

2. TERMS OF USE

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3. PROJECT AND FUNDING INFORMATION

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4. CONTENTS

Finite element models and images

The compressed files with "FE model INP" in the title contain the .INP files of all variations of the knee models tested in this study. These files can be read into the ABAQUS finite element software and by standard text editing software. Each files contain the finite element meshes, material settings, boundary conditions, progressive loading/constraint steps, and contact conditions.

1–RTKN0668 FE model INP files.zip	The models of Knee 1 (or archive code RTKN0668).
1-LTKN8941 FE model INP files.zip	The models of Knee 2 (or archive code LTKN8941).
1-LTKN1468 FE model INP files.zip	The models of Knee 3 (or archive code LTKN1468).
1-FE tibial contact pressure images.zip	This compressed file contains PNG image files showing the contact pressure maps from the finite element models of both medial and lateral tibial condyles.

File name codes used to identify the different cases are given below. These naming conventions are used for both the .INP model files and the .PNG image files.

Knee specimens	The three knees are identified by their codes: RTKN0668, LTKN8941, LTKN1468
Cartilage representation	The cartilage representation is indicated by "seg" for cases in which the cartilage has a non-uniform thickness directly segmented from imaging, and "uni" for cases in which the cartilage has a uniform thickness.
Meniscus inclusion	The inclusion or exclusion of the two menisci is indicated by "intact" (where the menisci are included) and "nomen" (where they are excluded).
Tibial constraint	The different tibial constraint cases are indicated by "fix" (where the tibia is constrained in all degrees of freedom) or "progFree" (where the experimental tibial freedom is replicated by progressive release of each degree of freedom).
Load matching experimental	Two of the files have two versions, where one version has an extension of either "_f200" or "_f80". These are the cases where the experimental load did not reach the intended 500 N. For those modelling cases two versions of provided. A version loaded to 500 N (with no additional file extension) and a version loaded to the lower load value achieved experimentally (either 80 N or 200 N).

Study data

2-Study results sheets.zip	This compressed file contains the .CSV files of model settings, model output measures and comparisons with experimental data.

Files within the compressed file are as follows.

Full_Model_Output_Data.csv	Case descriptions, model settings and measures from all Finite Element modelling cases in the study.
ExpFE_Contact_Area_nomen_fix.csv	Comparison of the contact area on the medial and lateral tibial condyles, for experimental and computational cases with no menisci and a fully fixed tibia.
ExpFE_Contact_Area_nomen_partFree.csv	Comparison of the contact area on the medial and lateral tibial condyles, for experimental and computational cases with no menisci and a partially free tibia.
ExpFE_ML_Force_Balance_nomen_fix.csv	Comparison of the percentage of force being carried by the medial versus the lateral tibial condyles, for experimental and computational cases with no menisci and a fully fixed tibia.
ExpFE_ML_Force_Balance_nomen_partFree.csv	Comparison of the percentage of force being carried by the medial versus the lateral tibial condyles, for experimental and computational cases with no menisci and a partially free tibia.
FE_Tibial_Movement_nomen_partFree.csv	The movement of the tibia in the computational cases with no menisci and a partially free tibia.
FE_Meniscus_Contact_Area.csv	Results from the intact tibiofemoral joint finite element models, showing the amount of contact area on the tibial cartilage from contact with the meniscus and from contact with the femoral cartilage.
FE_Meniscus_Load_Carried.csv	Results from the intact tibiofemoral joint finite element models, showing the amount of load applied to the tibial cartilage from contact with the meniscus and from contact with the femoral cartilage.

Experimental pressure data

The compressed files in this section contain data from pressure sensors within the tibiofemoral joint in the experimental specimens. This data has been recorded for three cadaveric knees tested in two states (with and without meniscus) and at two flexion angles (10 degrees and 20 degrees).

3-RTKN0668_pressure_sensor_data.zip The data recorded for Knee 1 (or archive code RTKN0668).

3-LTKN8941_pressure_sensor_data.zip The data recorded for Knee 2 (or archive code LTKN8941).

3-LTKN1468_pressure_sensor_data.zip The data recorded for Knee 3 (or archive code LTKN1468).

Photographs from lab dissection, potting and testing

The compressed files in this section contain photographs taken during the experimental work. These include the dissection steps, potting and testing. These photographs give a sense of the quality of the tissue of each sample.

4-RTKN0668_lab_photographs.zip The images taken of Knee 1 (or archive code RTKN0668).

4-LTKN8941_lab_photographs.zip The images taken of Knee 2 (or archive code LTKN8941).

4-LTKN1468_lab_photographs.zip The images taken of Knee 3 (or archive code LTKN1468).

Micro-Computed Tomography images of tibiofemoral joint with surrounding tissue dissected

5-Knee_CT_preview_slices.zip

The three-dimensional CT images in this section are large and will take some time to download. Preview images for each CT image are available in this compressed file.

The following details apply for the block of compressed CT images stacks immediately below.

Image: high-resolution peripheral quantitative computed tomography
Machine: XtremeCT, Scanco Medical AG, Switzerland
Resolution: isotropic voxel size of 82 µm
Format: DICOM image stack
Storage size: Each image stack ~3-5 Gb.

5-RTKN0668_mCT_intact.zip   Knee 1, full knee with patella

5-RTKN0668_mCT_dissected.zip   Knee 1, tibiofemoral joint, ligaments removed

5-RTKN0668_mCT_nomen.zip   Knee 1, tibiofemoral joint, no meniscus

5-LTKN8941_mCT_dissected.zip   Knee 2, tibiofemoral joint, ligaments removed

5-LTKN8941_mCT_nomen.zip   Knee 2, tibiofemoral joint, no meniscus

5-LTKN8941_mCT_nomen_femur.zip   Knee 2, just the femur, condyles cut off

5-LTKN1468_mCT_dissected.zip   Knee 3, tibiofemoral joint, ligaments removed

5-LTKN1468_mCT_nomen_femur.zip   Knee 3, just the femur

5-LTKN1468_mCT_nomen_tibia.zip   Knee 3, just the tibia

Magnetic Resonance Images of pre-dissection whole knee

6-Knee_MR_preview_slices.zip

The three-dimensional MR images in this section are large and may take some time to download. Preview images for each MR image are available in this compressed file.

For all MR images of all knees:
Format: DICOM image stack
Storage size: Each image stack 15-30 Mb

Machine used for all MR images of RTKN0668 (Knee1):
3 Tesla MRI scanner (Siemens Magnetom Prisma, Erlangen, Germany)
using a 15 channel transmit/receive knee coil (Siemens, Erlangen, Germany)

Machine used for all MR images of LTKN8941 (Knee 2) & LTKN1468 (Knee 3):
3 Tesla MRI scanner (Siemens Magnetom Vida, Erlangen, Germany)
using an 18 channel transmit/receive knee coil (Siemens, Erlangen, Germany)

The various MR sequences taken of the three cadaveric knees are described below.
Some were taken for all three knees and others for only one or two of them.

The following details apply for the block of compressed MR images listed immediately below.
Image sequence: MRI - 3D Double Echo Steady State (DESS)
   Resolution: 0.36 x 0.36 x 0.7 mm3, 144 slices
   Objective in this work: Cartilage imaging & assessment

6-RTKN0668_MR_DESS.zip   Knee 1
6-LTKN8941_MR_DESS.zip   Knee 2
6-LTKN1468_MR_DESS.zip   Knee 3

The following details apply for the block of compressed MR images listed immediately below.
Image sequence: MRI - 2D Proton density weighted, Turbo spin echo, No fat saturation
   [similar to sequences in the Osteoarthritis Initiative database, with higher resolution]
   Slice direction: Sagittal
   Resolution: 0.3 mm in plane, 1.6mm slice thickness, 62 slices, No slice gap
   Objective in this work: Anatomical details

6-RTKN0668_MR_2D_TSE_SAG_IW_0.3pix.zip   Knee 1
6-LTKN8941_MR_2D_TSE_SAG_IW_0.3pix.zip   Knee 2
6-LTKN1468_MR_2D_TSE_SAG_IW_0.3pix.zip   Knee 3

The following details apply for the block of compressed MR images listed immediately below.
Image sequence: MRI - 2D Proton density weighted, Turbo spin echo, With fat saturation
  [similar to sequences in the Osteoarthritis Initiative database, with higher resolution]
  Slice direction: Coronal
  Resolution: 0.3 mm in plane, 1.6mm slice thickness, 62 slices, No slice gap
  Objective in this work: Bone marrow lesions, Cartilage lesions, inflammation, meniscal tears, parameniscal cysts, meniscal extrusion

6-RTKN0668_MR_2D_TSE_COR_FS_IW_0.3pix.zip　　　　Knee 1
6-LTKN8941_MR_2D_TSE_COR_FS_IW_0.3pix.zip　　　　Knee 2
6-LTKN1468_MR_2D_TSE_COR_FS_IW_0.3pix.zip　　　　Knee 3

The following details apply for the block of compressed MR images listed immediately below.
Image sequence: MRI - 2D Proton density weighted, Turbo spin echo, With fat saturation
  Slice direction: Transverse (axial)
  Resolution: 0.3 mm in plane, 1.6 mm slice thickness, 62 slices, No slice gap
  Objective in this work: Meniscal tears, Bone marrow lesions

6-LTKN1468_MR_2D_TSE_TRA_FS_IW_0.3pix.zip　　　　Knee 3

The following details apply for the block of compressed MR images listed immediately below.
Image sequence: MRI - 2D T2-weighted, Turbo spin echo, No fat saturation
  Slice direction: Sagittal
  Resolution: 0.3 mm in plane, 1.6 mm slice thickness, 60 slices, no slice gap

6-RTKN0668_MR_2D_T2_noFS_TSE_SAG_IW_0.3pix.zip　　Knee 1
6-LTKN8941_MR_2D_T2_noFS_TSE_SAG_IW_0.3pix.zip　　Knee 2
6-LTKN1468_MR_2D_T2_noFS_TSE_SAG_IW_0.3pix.zip　　Knee 3

The following details apply for the block of compressed MR images listed immediately below.
Image sequence: MRI - 2D T2-weighted, Turbo spin echo, With fat saturation
  Slice direction: Sagittal
  Resolution: 0.3 mm in plane, 1.6 mm slice thickness, 60 slices, no slice gap
  Objective in this work: Bone marrow lesions, Cartilage lesions, Inflammation, Haem arthrosis, Meniscal root tears, Parameniscal cysts

6-RTKN0668_MR_2D_T2_FS_TSE_SAG_IW_0.3pix.zip　　　Knee 1
6-LTKN8941_MR_2D_T2_FS_TSE_SAG_IW_0.3pix.zip　　　Knee 2

The following details apply for the block of compressed MR images listed immediately below.
Image sequence: MRI - 3D T1 VIBE, with water excitation
  Slice direction: Coronal
  Resolution: 0.4 mm x 0.4 mm x 0.7 mm
  Objective in this work: Assessment of the bone as well as other soft tissue structures such as ligaments

6-LTKN1468_MR_T1_vibe_we_cor iso_High res.zip   Knee 3

The following details apply for the block of compressed MR images stacks immediately below.
Image sequence: MRI - 2D, Multi echo data image combination (MEDIC)
  Slice direction: Coronal
  Resolution: High in-plane res, 0.2 mm x 0.2 mm x 2 mm
  Objective in this work: Cartilage & ligament assessment

6-LTKN1468_MR_medic_cor.zip   Knee 3

5. METHODS

Specimen codes

Codes linking the simple specimen numbers used in the study data sheets and associated paper, to those used in the wider knee database. [Filename: **specimen_codes.txt**]

Method documentation

Details of the experimental and computational methods and the details of the comparisons made in the results data sheets, are given in this document. [Filename: **method_documentation.pdf**]