**In vivo** high-resolution MRI (7T) of femoro-tibial cartilage changes in the rat anterior cruciate ligament transection model of osteoarthritis: a cross-sectional study

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**Abstract**

**Objective.** To assess OA-related changes in mean compartmental femorotibial cartilage thickness in rat knees by three-dimensional (3D) MRI (7T).

**Methods.** MRI was performed **in vivo** at 7T on OA and untouched contralateral knee joints. Gradient Echo Fast Imaging 3D MR images were acquired sequentially in surgically induced OA (D0) in 40 Wistar rats (anterior cruciate ligament transaction). Mean femoral (trochlear, lateral and medial) and tibial (lateral and medial) cartilage thicknesses were quantified from a 2D MRI slide in weight-bearing areas and from a 3D MRI data set. At each time-point [Day (D)8, D14, D21, D40 and D60], eight animals (16 knees) were sacrificed for concomitant histomorphometry.

**Results.** As body weight dramatically increased throughout the experiment (+150%, baseline vs endpoint), all compartmental mean cartilage thicknesses noticeably decreased (D8, D14) and then remained relatively stable. Femoral compartments in OA knees were thinner at the end of the experiment than in contralateral age-matched knees. Conversely, lateral and medial tibial cartilages were thicker than controls. Histological correlation was significant only in untouched healthy cartilages (3D better than 2D).

**Conclusions.** 3D MRI (7T) enables **in vivo** monitoring of compartmental changes in OA-related femoro-tibial rat cartilage thickness vs contralateral age-matched knees.

**Key words:** Cartilage thickness, Rat knee, Magnetic resonance imaging, Experimental osteoarthritis, Volume.

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**Introduction**

OA is a progressive disorder of the joints caused by a gradual loss of hyaline cartilage resulting in the development of bony spurs and cysts at the margins of the joints. Advances in medical imaging, and especially MRI, offer hope in terms of early diagnosis and therapeutic follow-up both in clinics [1] and in animal models of OA [2]. Unlike humans, rats rarely develop spontaneous age-related OA. In contrast, as an archetypal pharmacological preclinical tool, many experimental models of rat OA have been developed, and their histological and biochemical characteristics are well established [3]. Since in clinical studies on chondroprotection MRI is not actually a classical primary endpoint, the contribution of such experimental models is thus necessary to validate it. These models may enable researchers to quantify cartilage damage during active disease and the action of potential chondroprotective agents, thus allowing the establishment of histological and biochemical correlations with cartilage signal intensity (ultrastructure) or volume at
MRI [4]. Previous magnetic resonance (MR) studies in rat experimental OA (4.7T) have been performed ex vivo on cadaveric knees with a good histological correlation [5, 6]. In vivo, MR studies of the rat knee remain limited to synovitis assessment during experimental arthritis at 2–7T [7–10].

During the past few years, high-field quantitative MRI (qMRI), which allows high-resolution (HR) imaging, has become a powerful research tool to examine and visualize hyaline cartilage of small joints non-invasively in vivo [11]. Recent studies have shown that qualitative assessment of degenerative joint disease based on MR images was reliable and gave good histological correlations [2]. The ability to show pathological changes on a 7T MR imager throughout the time-course of the disease from three-dimensional (3D) data sets in rat [12] and guinea pig [13] knee joints was also recently demonstrated [14]. However, such quantitative imaging modalities for accurate determination of cartilage volume and thickness still need to be confirmed in vivo in the rat knee [15].

Previous in vivo follow-up studies using 2D and 3D qMRI have only been conducted in the guinea pig model [2] and no study has used MRI to monitor the volumic progression of experimental OA in the rat knee. We felt it was important to assess the power of 3D qMRI in comparison with histology to detect OA-related variations in femorotibial cartilage. The purpose of our study was thus to investigate the usefulness of 3D high spatial resolution qMRI in characterizing changes in femorotibial cartilage volume/thickness during experimentally induced OA. In this cross-sectional study, histomorphometry was concomitantly assessed in order to correlate structural OA-related variations.

**Material and methods**

**Animals**

Male Wistar rats (Charles River Laboratories, L’Arbresle, France) aged from 4 weeks to 3 months were used in this work. They were housed in plastic cages with sawdust bedding and maintained at 21°C with a 12 h/12 h light/dark cycle. Rats were fed a standard diet and had access to tap water ad libitum. Ethics guidelines for experimental investigations in animals were respected throughout the study period, and the experimental protocol was used after acceptance by the local (Lyon University) Animal Experimentation Ethics Committee. Both knees (left healthy and right OA knees) were successively studied.

As previously described [16], rats underwent an anterior cruciate ligament transection (ACL T) under anaesthesia [i.p. injection of a mixture of acepromazine (ACP) at 1.25 mg/kg and ketamine at 38 mg/kg]. A parapatellar skin incision was performed first on the medial side of the right knee joint, and second on the medial side of the patellar tendon. The patella was then dislocated laterally to provide access to the joint space and ACL was transected in the flexed knee. A positive anterior drawer test validated complete transection of the ligament. The joint was then irrigated with sterile saline to avoid ancillary inflammation, and a custom-made suture was processed: the incision was closed in two layers. The joint capsule was sutured independently from peripheral tissues using dissolvable 5-0 Vicryl sutures, and the skin closed by interrupted sutures using 5-0 braided silk (Ethicon, Johnson & Johnson Medical Products, St-Stevens-Woluwe, Belgium). Untouched left knees were used as age-matched controls.

A home-made [17] radio frequency (RF) knee coil was placed around the operated/control knee (Fig. 1), and the leg was maintained in extended position with medical adhesive tape in order to avoid motion. Rats were kept anaesthetized with isoflurane (2.7% at 1 l O2/min) throughout the positioning and imaging processes. Temperature-controlled gaseous anaesthesia was supplied in the magnet via a facemask. Animals were laid down in the supine position on a water-heating bed, which was gently and precisely pushed into the centre of the magnet. The animal’s ventilation and temperature were monitored continuously during MR acquisition. OA rat groups were studied on Day (D)8, D14, D28, D40 and D60 (endpoint) after OA induction (D0) performed in young rats (175 g).

**MRI protocol**

Rats were imaged in vivo for 45 min in a 7 Tesla BioSpec MR imager (Bruker, Ettlingen, Germany) equipped with 400 mT/m gradient amplitudes. After preliminary tests [11], the optimized acquisition parameters were achieved and set as follows: fat suppressed (FS) 3D high spatial resolution gradient echo fast imaging (GEFI, also called 3D SPGR) sequence with repetition time: 50 ms, echo time: 3.6 ms, flip angle: 25°. A total of 128 adjoining slices (thickness: 94 μm) were obtained with a 26 × 26 mm2 field of view and an image matrix of 512 × 512 pixels leading to a 51 × 51 × 94 μm3 voxel. Rapid acquisition with relaxation-enhanced (RARE) scout view was performed both to check that the knee position in the coil was correct and to align the 3D HR GEFI slices orthogonally to the knee anteroposterior flexing axis [18]. A sagittal reconstruction of the data was chosen, because this plane allows better visualization of all knee cartilage compartments by minimizing partial volume effects. The acquired volume completely covered the joint.

**MR image processing**

Femorotibial cartilage segmentation and volume. The collected 3D-MRI data sets were used to compute the femoral (whole-condylar groove) and tibial (medial and lateral tibial plateaux) articular cartilage volumes. An interactive touch-sensitive screen with a 1280 × 1024 pixel matrix (Interactive Pen Display PL-720; Wacom Europe GmbH, Germany) was used [19]. The knee cartilage compartments were drawn directly on this screen using the pen provided. Manual contouring and further image computations were done using AMIRA software (Amira 4.1; Mercury Computer Systems SAS, France). As done in the clinics, whole articular cartilage was segmented on
Fig. 1 Schematic flow chart of the methodology used in the present study: MR study, histological analysis and data post-processing (segmentation, mean thickness calculation and 3D rendering).
each MRI slice where cartilage borders could easily be defined, in order to reduce the partial volume effect encountered in the medial and lateral extreme images. Each segmented area was then assigned to its corresponding cartilage compartment using grey-scale-coded labels.

The segmentation procedure was done by a trained observer (J.C.G.) who was blind to the rats’ identity. The time needed to manually segment all the slices covering the cartilaginous joint was 4–5 h for each knee. Quality control of all segmentations was performed by a single reader (P.G.). Our previous results [15] revealed inter-observer errors in precision, expressed as the percentage root mean square of coefficients of variation [20], of 9.1, 6.2, 9.6 for the femoral, medial and lateral tibial compartments, respectively. In the case of intra-observer reproducibility, we obtained 2.1, 3.2, 2.5 for the cartilage compartments cited above.

2D measurement in weight-bearing areas. In the first step, after the manual segmentation procedure, the resulting labelled masks were used to proceed with the computation of cartilage mean thickness in weight-bearing areas (detailed below in ‘Histological analysis’ section). Euclidean distance maps were generated from the masks. These distance values were then averaged to compute the mean thickness of tibial and femoral weight-bearing cartilage. The same procedure was used on the corresponding weight-bearing histological scans (see below). Finally, the MRI and histological mean thicknesses were compared to evaluate the ability of MRI to assess variations in femorotibial cartilage in untouched healthy and OA knees (Fig. 1).

3D measurements. On the resulting masks, an integration procedure was performed to count each labelled voxel. This process gives three articular cartilage volumes (femoral groove, medial and lateral tibial plateaux) by multiplying the number of labelled voxels by the real voxel dimensions. A 3D rendering was also obtained in the AMIRA environment to visualize the cartilage compartments, and the femoral cartilage was then divided into three sub-regions [21]: femoral patellar, femoral medial and femoral lateral regions. To minimize growth-related modifications [22], in the next step, we measured the mean thickness of various compartments (volume normalized to the total area of sub-chondral bone [23–25]). In each compartment, we used mean cartilage thickness (expressed in micrometres) over the total area of subchondral bone. The computation included denuded areas of subchondral bone with 0 μm cartilage thickness but did not include cartilage covering the osteophytes [26].

Histological analysis
Immediately after MRI, the rats were sacrificed and the whole knee joints were dissected, fixed in 4% formal, decalcified with Rapid Décalcifiant Osseux (RDO, Apex, Canada), dehydrated through ascending series of ethanol baths using an automated tissue processing apparatus, and then embedded in paraffin. One 5-μm sagittal slice was obtained in two locations in each knee weight-bearing area, guided by a visual control of the anterior and posterior meniscal horns:

- medial femorotibial weight-bearing area, including the medial femoral condyle and medial tibial plateau; and
- lateral femorotibial weight-bearing area, including the lateral femoral condyle and lateral tibial plateau.

To measure cartilage thickness, slices were stained with haematoxylin–eosin–saffron and were photographed (×4 magnification; 1 pixel = 14.7 μm) with a colour digital video camera (WV-CL350; Panasonic, Osaka, Japan), and saved in tagged image file format at a workstation (Indy; Silicon Graphics, Mountain View, CA, USA). The haematoxylin–eosin–saffron-stained pictures were used for manual cartilage segmentation and for mean thickness computation as follows (cartilage delineation in each compartment took 5 min). As shown in Fig. 1, after the manual segmentation procedure, the resulting labelled masks were used to proceed with the computation of mean cartilage thickness in weight-bearing areas. In the first step, Euclidean distance maps were generated from the masks. All computed values were then displayed on a colour-coded distance map. In the second step, the skeleton of the labels was extracted. Skeletonization is an image processing operation that reduces input shapes to axial ‘stick-like’ or ‘one pixel in width’ representations. It corresponds by definition to the location of the local maxima of the Euclidean distance map. By merging the Euclidean distance map with the corresponding skeleton, we obtained the exact location and value of each maximal cartilage thickness pixel. These distance values were then averaged to compute the mean thickness of tibial and femoral weight-bearing cartilage.

Statistical analysis
Data were expressed as mean (s.d.) for each compartment. The significance of differences between mean values of various age-matched groups was assessed by a one-way analysis of variance (ANOVA) followed, if significant, by a Tukey–Kramer test. In surgically induced OA rats, values for the left normal knee and right OA knees were compared using a two-tailed paired Student’s t-test. Correlations between MR and histological data were examined via linear regression analysis followed by a non-parametric Spearman’s test. R represents the Pearson product–moment correlation coefficient obtained with a multivariate correlation analysis adjusted for each group: $R < 0.3$ = little or no association; $0.3 < R < 0.7$ = moderate correlation; $R > 0.7$ = strong correlation ($P < 0.05$ non-parametric Spearman’s test). Additionally, a Bland–Altman analysis quantified the observed differences between MRI and histology (the gold standard). Statistical analyses were performed using JMP 6 SAS Statistical Discovery. Graphs were plotted using Prism 4 GraphPad. Statistical significance was set at $P < 0.05$. 
Results

On D0, the body weight of young rats was ~170 g. Subsequently body-weight gain increased progressively in concordance with the standard of our chosen rat strain. At the endpoint (D60), mature rats weighed ~420 g (+150%). The differences between the groups were statistically significant at any given time point.

2D profiles of cartilage thickness in weight-bearing areas and histological correlations

Untouched healthy knees. In the medial compartment, cartilage thickness decreased progressively and significantly with the maturation process in the femoral compartment (Fig. 2). Conversely, the mean tibial cartilage thickness remained unchanged throughout the experimental period. When all the individual compartmental values were taken together, there was a moderate correlation between MR and corresponding histological data in the femur ($r = 0.42$, $P < 0.05$) but not in the tibia ($r = 0.07$). In the lateral compartment, there was a significant and progressive decrease in cartilage thickness in both the femur and the tibia. Again, global compartmental correlation coefficients were moderate, and were smaller for the tibia ($r = 0.31$, NS) than for the femur ($r = 0.54$, $P < 0.05$). As care had to be taken when the number of samples used in the evaluation was low, we pooled all the histomorphometric and MR measurements (142 workable paired values) concerning the medial and lateral femorotibial compartments. As shown in Fig. 2, the global Pearson’s correlation coefficient was moderate ($r = 0.34$, $P < 0.05$). Otherwise, according to the Bland–Altman results, we observed that MRI overestimated cartilage thickness compared with histological measurements, especially for small values, due to a decrease in cartilage thickness (2–3 pixels on MR scans) and the poor delineation of hyaline cartilage vs subchondral bone in mature rats.

OA knees. In the medial compartment, the decrease in femoral cartilage thickness was similar in both OA and control knees (MF). In contrast, there was progressive thickening of the tibial cartilage (MT), which was significantly greater than that in normal age-matched knees from D30 to D60. Slight, but non-significant thinning of the femoral cartilage (LF) occurred progressively in the lateral compartment. Conversely, tibial cartilage (LT) thickened significantly from D28 to D60 (Fig. 2), reflecting compartmental chondral hypertrophy. When considering all the individual compartmental values together, there was only a moderate inverse correlation between MR and corresponding histological data for the medial femoral compartment ($r = -0.36$, $P < 0.05$). The global correlation between the MR values of the four compartments and their respective histological counterparts (Fig. 2) was very poor and not significant ($r = -0.09$; NS). According to the Bland–Altman results, we observed a positive bias between MRI and histology, implying that MR overestimated thickness compared with histological data.

Mean 3D MR cartilage thickness

Untouched healthy knees. In the medial compartment (Fig. 3), mean cartilage thickness in all areas decreased from D8 to D28, and remained stable thereafter. When the individual values were taken together, there was a moderate correlation between MR and corresponding histological data for both the femur ($r = 0.43$, $P < 0.05$) and the tibia ($r = 0.44$, $P < 0.05$). In the lateral compartment, cartilage thickness in all areas also decreased from D8 to D28, and remained stable thereafter. Again, global correlation coefficients were moderate, and were smaller for the tibia ($r = 0.36$, $P < 0.05$) than for the femur ($r = 0.58$, $P < 0.05$). In the trochlear compartment, the profile of mean cartilage thickness was similar, average values were significantly smaller on D8 than on D14 and D28 and remained relatively stable thereafter. As histological measurements were only performed in weight-bearing medial and lateral femorotibial areas, no similar correlation was observed for the trochlea.

When all the histomorphometric and MR measurements (142 workable paired values) concerning medial and lateral femorotibial compartments were pooled, the overall Pearson’s correlation coefficient was moderate ($r = 0.41$, $P < 0.05$), better than that obtained with 2D measurements. Otherwise, according to the Bland–Altman results, we observed that MRI overestimated the cartilage thickness assessed by histology (+13.5 μm, corresponding to ~10% of the overall mean value).

OA knees.

(1) Medial compartment: the decrease in femoral cartilage thickness was similar in both OA and contralateral age-matched control knees (MF) from D8 to D28 (Fig. 3). Medial femoral OA cartilage was thinner on D40 and on D60. In contrast, medial tibial OA cartilage (TM) was significantly thicker than in normal age-matched knees from D28 to D60, reflecting compartmental chondral hypertrophy.

(2) Lateral compartment: a slight, non-significant thinning of femoral cartilage (FL) occurred progressively, and mean femoral cartilage thickness was significantly thinner only on D60. In contrast, tibial cartilage (TL) thickened significantly from D40 to D60 in comparison with contralateral age-matched knees. The global correlation between the MR values of the four compartments and their respective histological counterparts was very poor (not significant).

(3) Trochlear compartment: there was initial thinning of OA FT cartilage, which then remained relatively stable, mean cartilage thickness being significantly thinner than in age-matched knees on D14, D28 and D60.

As depicted in Fig. 4, MR scans demonstrated an intense synovial effusion in OA knees on D8 and D14. Later scans, on D40 and D60, revealed epiphyseal remodelling. No subchondral abnormality was revealed in either OA or healthy contralateral control age-matched knees.
throughout the experiment using 3D HR GEFI. Medial femoral erosion was revealed in weight areas from D28.

**Discussion**

The present results demonstrate the feasibility of 7T qMRI in depicting changes in \textit{in vivo} compartmental thickness/volume during surgically induced OA in rat knee. To the best of our knowledge, this work is the first \textit{in vivo} 3D study of healthy and OA femorotibial cartilage-related changes in young rats. Until now, no studies focusing on volumetric quantification of cartilage MR in small rodents \textit{in vivo} have been published. Changes in femorotibial cartilage are of great interest in studying the structural progression of OA, because changes in thickness can be localized in particular compartments. Additionally, concomitant erosion (thinning), oedema (thickening) and subchondral changes may alter the sensitivity of a global measurement, thus reinforcing the interest of monitoring compartmental changes in cartilage thickness.

![Fig. 2](image_url) 2D profiles of MR femorotibial cartilage thickness and global histological correlations in OA (solid line) and untouched contralateral control (dashed lines) rat knees. Values are the mean (S.D.), \(n=6-8\) values for each key point. Cartilage thickness (ThC) was assessed in weight-bearing areas of femoropatellar joints (medial and tibial) on MR and corresponding histological scans. Knee OA was induced surgically in the right knee at D0. Comparisons were made between OA knees (right) and contralateral age-matched healthy knees (control, left) with a two-tailed paired Student’s \(t\)-test and correlation with (*\(P < 0.05\), **\(P < 0.0001\)). FM: femoral medial; FL: femoral lateral; TM: tibial medial; TL: tibial lateral. Correlation and regression analysis (control and OA graphs at the bottom) show the relationship between histological and MR measurements (see ‘Materials and methods’ section).
Three innovations were needed for this MR study: the design of a rat-specific RF coil [17], the development of an optimized MRI sequence with specific parameters [11] and standardization of the segmentation method [15]. We used the MR sequence that best delineated the cartilage from the surrounding tissues, i.e. 3D fat-suppressed spoiled gradient echo. However, it should be noted that 3D FS SPGR (also referred to as GEFI) is relatively insensitive for bone marrow oedema [27]. To date, a fully automated technique for cartilage segmentation has not been made available due to the inherently low contrast between cartilage and surrounding tissues, especially in mature rats. In our experiment, the segmentation procedure was time-consuming requiring 4–5 h/rat knee for a trained operator. In the present study, the cartilage was segmented slice-by-slice using a manual technique, because the semi-automatic Amira’s Segmentation Editor (although excellent for mouse synovium [28]) was less concordant with the histological data (internal results). In addition, such segmentation overestimates cartilage thickness (see below).

In fact, MRI measurements were calculated taking into account the 3D data set, whereas histological assessments were made on 2D slices. The slice orientation could be influenced by the sample preparation. We attribute the poor correlation observed in this study to rudimentary linear measurement combined with rather limited MR resolution. It is noteworthy that qMRI often
overestimated cartilage thickness compared with histology, which was used as a reference. This may be due to (i) the fact that cartilage morphology could be altered by histological methods, especially dehydration [29]; or (ii) the segmentation process (it is easier to exclude the deep calcified layer in histological than MR scans, due to the staining-related individualization). Additionally, OA-related pannus formation [16] and ancillary joint effusion led to enlargement of the joint space. The increase in the synovial water content and the osmotic pressure due to the inflammatory response may also introduce biases by decreasing the synovial signal and that of the nearby OA cartilage [12].

ACLT in rats is a widely used animal model for investigating the development of knee OA longitudinally [30]. This animal model mimics the gene expression [31], histological [32], radiological [33] and MR changes [6] seen in human OA, supporting its relevance for evaluating chondroprotective drugs [34, 35] or imaging techniques [36]. Forced mobilization [37] and meniscectomy [38] increases its severity. In our histological experiment, this model combines an intense synovium proliferation (pannus [16]) with a large initial SF effusion, progressive erosion of femoral medial cartilage with peripheral osteophytosis combined with medial tibial chondral thickening. From an MR point of view, these findings are significantly supported by

FIG. 4 MR scans and 3D rendering of femorotibial cartilage in normal (left, control, on the right side of the figure) and age-matched OA (right, on the left side of the figure) rat knees at key points. OA was induced surgically at D0 in the right knee. Note the initial joint effusion in OA knees, and their progressive epiphyseal remodelling. Subchondral exposure appeared on D28 in the medial femoral compartment (green). Medial tibia is in blue and lateral tibia in purple.
medial and lateral tibial MR thicknesses. This tibial oedema without erosion is inherent in the relative protection conferred by the adjacent medial meniscus. Such focal increase in cartilage thickness has already been reported in experimental OA in rabbit [39], although other experimental animal studies have shown that cartilage hypotrophy occurs in early OA [40]. Similar models in other species indicate a mixture of swelling (disruption of collagen network) and hypertrophy. Overestimation of cartilage thickness on MR scans at 7T has also been reported [12], especially in diseased cartilage. In our study, this question remains open, because although a moderate correlation was found for normal cartilage, no significant correlation was found for OA cartilage, especially for chondral oedema, as reflected by the highest values. It should be noted that as both water and lipids were eliminated in the histological procedure, the histological underestimation of OA MR cartilage thickness is believed to be mainly due to dehydration. However, for further longitudinal studies, without such sequential sacrifice, under or overestimation of the cartilage thickness will not be a serious problem because it will still allow longitudinal changes in the same joint to be quantified [14].

Limitations of the study

Artefacts. Artefacts like partial volume effect may occur when two or more fluids or tissues with different signal intensities partly occupy a voxel and produce a signal intensity that is intermediate between the two. A boundary between the two tissues or fluids is present within the voxel. Fibre partial volume effect involving chondral collagen fibres surrounded by non-fibrous tissue or other fibres with the same or different orientation was inherent to pannus, SF and subchondral bone adjacent to the cartilage. We tried to reduce this bias by strictly respecting classical anatomical landmarks observed in femotibial chondral areas (menisci, tibial spine, growth plate, cartilage borders, etc.). Additionally, a potential chemical shift artefact was reduced by using a FS technique. FS enhances the contrast in cartilage and it has been reported that it can lead to better reproducibility of volumetric measurements [41]. Finally, because the spatial resolution, signal-to-noise ratio, contrast-to-noise ratio and acquisition time are mutually interdependent, optimizing one of these parameters at a given magnetic field strength requires sacrifices in the others. We thus chose the best compromise for our study requirements. Thinner slices could have been obtained to reduce the partial volume effect, however, the cost incurred in increased scan time and subsequent loss of signal-to-noise ratio would have been excessive.

Time course. The natural history of the model was not followed to the point where cartilage erosion is more general. The signal is mixed at these time points because the relationship with histology varies from moderate (in healthy knees) to very poor (in OA knees).

Conclusion

Our pilot study with in vivo 7T MRI-based quantification of healthy and OA rat knee demonstrated the ability of 7T HR MRI technique in assessing OA-related changes in femotibial cartilage volume/thickness in the various femotibial compartments near the resolution of histology without the need for sequential animal sacrifice. 3D measurement of thickness has the advantage of being independent of bone size and less subject to change in positioning of the knee. In addition, it enables zonal examination in predefined anatomical areas. The evaluation of OA vs strictly age-matched knees is needed to avoid the bias inherent in the maturation process in the young rats usually used in experimental models.

Finally, further longitudinal studies during rat experimental OA are needed to confirm the accuracy of 3D 7T MRI in non-invasive quantification of therapeutic interventions on structural changes in cartilage, especially in the progression of compartmental chondral OA-related modifications (thinning/hypertrophy).

Rheumatology key messages

- 7T MRI provides in vivo measurements of cartilage thickness/volume in normal/OA rat knees.
- ACLT in the rat knee induces concomitant femoral cartilage thinning and tibial chondral thickening.
- HR MRI better depicts experimental chondral thickening than histology due to ancillary dehydration processing.

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