Articular cartilage in adults has a limited capacity for self-repair after a substantial injury. In addition to bone marrow stimulating procedure surgical therapeutic efforts to treat cartilage have focused on delivering new cells capable of chondrogenesis into the lesions. In the classic autologous chondrocyte transplantation (ACT) technique chondrocytes are isolated from small slices harvested from a minor weight-bearing area of the injured knee. The extracted cells are then cultured and once a sufficient number of cells has been obtained, the chondrocytes are implanted into the cartilage defect using a periosteal patch over the defect as a method of cell containment. Further improvements in tissue engineering have contributed to the next generation of ACT techniques, where cells are combined with resorbable biomaterials, as in matrix associated autologous chondrocyte transplantation (MACT). These materials secure the cells in the defect area and enhance their proliferation and differentiation.

MR imaging as a non-invasive technique is the method of choice in the follow-up of patients with these different surgical cartilage repair techniques. MR imaging of the morphology of cartilage and cartilage repair tissue has significantly improved in recent years due to the development of clinical high-field MR systems operating at 3 Tesla. The improved performance has also been achieved as a result of the higher gradient strengths and the application of dedicated coils with modern configuration such as phased array coils. MR should be performed with cartilage sensitive sequences such as fat-suppressed PD/T2-FSE or 3D GRE sequences, which provide a good SNR and CNR. High spatial resolution is mandatory and is necessary for a better visualization of graft morphology, in particular for the evaluation of transplant integration to the adjacent hyaline cartilage and bone. MR imaging also helps to evaluate the filling of the defect by repair tissue, the surface and structure of repair tissue, the signal intensity of repair tissue with respect to the time interval to surgery and the status of the subchondral bone. Complications such as periosteal hypertrophy, incomplete and complete delamination, arthrofibrosis and adhesions, incongruencies of the cartilage surface at the repair site, graft failure and reactive changes of the joint such as effusions and synovitis can be visualized. A recent development of high resolution isotropic 3D sequences will further improve the visualization of transplants from different planes and views including virtual arthroscopy.

The evaluation of the success of cartilage repair procedures requires particular grading systems, one of which is MOCART. The validity and reliability of this system has been evaluated for the assessment of matrix-associated autologous chondrocyte transplantation (MACT) in the knee, using 9 pertinent variables. An almost perfect agreement (ICC >0.81) was found for 8 of the 9 variables. When comparing the MRI scores with clinical outcome (knee related quality of life) 2 years after ACT a statistically significant correlation was found for "filling of the defect," "structure of the repair tissue," "changes in the subchondral bone," and
"signal intensities of the repair issue". With the development of isotropic high resolution 3D sequences, 2D MOCART score was further developed into a 3D MOCART score with an improved visualization of the morphological aspects of cartilage repair tissue.

In addition to morphological MR imaging of cartilage repair tissue, an advanced method to non-destructively and quantitatively monitor parameters reflecting the biochemical status of cartilage repair tissue is a necessity for studies which seek to elucidate the natural maturation of ACT and MACT grafts and the efficacy of the technique. For example, glycosaminoglycan (GAG) are known to be responsible for stiffness properties of cartilage, which gains even more importance with cartilage implants and the content and organization of the collagen network reflects further mechanical properties of cartilage.

Therefore, several MR techniques were developed, which allow detection of biochemical changes that precede the morphological degeneration in cartilage and follow cartilage transplantation. To date, the most promising technique for visualizing the GAG content in repair tissue is a contrast-enhanced T1 mapping technique, called delayed gadolinium-enhanced MRI of cartilage (dGEMRIC) with the distribution of the contrast agent in an inverse relationship to GAG in cartilage. With the introduction of ultra-high field MR systems operating at 7 Tesla sodium imaging gains more importance, since the sodium concentration in cartilage and repair tissue is directly correlated to the GAG concentration. Most recently Chemical Exchange Saturation Transfer (CEST) called gag CEST was introduced which uses the chemical exchange of labile protons with bulk water. It was shown that labile –NH (δ=3.2 ppm offset from the water resonance) and –OH (δ=0.9 to 1.9 ppm) protons of GAG can be used as CEST agents through selective saturation of their resonance signals.

While GAG content reflects stiffness properties of repair tissue, the organisation of the collagen matrix in repair tissue over time is important, too, as failure within the collagenous fibre network is considered to entail further cartilage breakdown. The extracellular matrix of native cartilage is shaped by a highly organized collagen network, which is the basis of the histological zones. Under ideal circumstances cartilage repair tissue produced following ACI and MACT should, over time, develop a collagen network with a similar shape and collagen concentration to normal hyaline cartilage. Quantitative T2 mapping has been reported to be sensitive to collagen content and organization. With high resolution MR T2 mapping it is also possible to assess zonal variations within the cartilage layer which is a marker to differentiate between repair tissues based on different cartilage repair surgeries. Thus, no difference between deep and superficial aspects within cartilage repair tissue and in total shorter T2 values compared to healthy cartilage after MFX therapy was found indicating disorganized and more fibrous tissue. After MACT, zonal variation with T2 mapping could be measured, however compared to healthy cartilage sites the increase from deep to superficial zones was less pronounced.

In summary, morphological and biochemical MR help to monitor the normal development of the ultrastructural composition of repair tissue after ACI and MACT and help to identify complications as well as provide information on suboptimal ultrastructure of repair tissue (low GAG content, disorganized collagen fiber network), although the morphological scoring may yield a good outcome.