Examining Musculoskeletal Implants with Lower-Field MRI

Bianca Samsula[1], Simon Balzer[2], Mathias Nittka, Ph.D.[2]; Markus Lentschig, M.D.[1]

[1]ZEMODI - MVZ Zentrum für moderne Diagnostik, Bremen, Germany
[2]Siemens Healthineers, Erlangen, Germany

Implant surgery for musculoskeletal diseases has been progressing steadily in recent years, and the number of operations is continually growing. In Germany alone, some 200,000 hip replacements are performed each year, along with roughly 150,000 knee replacements. Improvements and new developments in implant technology mean that other joint replacement surgeries (such as for the shoulder, elbow, ankle, or knuckles) are also being performed increasingly frequently [1].

This is leading to rising demand for diagnostic imaging connected to pathologies at or around these implants*. Since the established methods of X-ray and CT imaging are of limited diagnostic value, patients are increasingly being referred to MRI.

With conventional high-field MRI scanners, it is difficult to examine body regions that contain metallic implants: The large difference in magnetic susceptibility between metal and the surrounding tissue causes significant local distortion of the magnetic field, which produces the familiar image artifacts in the region of the implant. Even when using advanced applications like WARP and SEMAC, the image quality on conventional 1.5T and 3T MRI systems remains limited, making it difficult to diagnose the pathology.

With a low field strength of 0.55T, the systems of the MAGNETOM Free. Platform have the advantage of producing significantly fewer susceptibility artifacts than is commonly the case with high-field systems. With far fewer distortions and artifacts in the direct vicinity of implants, these lower-field scanners make it possible to identify pathologies better than with high-field systems, despite the lower resolution and signal-to-noise ratio. Like imaging at higher field strengths, these examinations use turbo spin echo (TSE) sequences with optimized acquisition parameters that are activated via the WARP option in the sequence. Increased excitation and readout bandwidths are crucial here, especially in combination with STIR technology as a more robust alternative to conventional spectral fat saturation for fat suppression.

In addition to established advanced acceleration techniques (parallel imaging and Simultaneous Multi-Slice acquisition), deep-learning-based image reconstruction methods offer enormous potential – now also at lower field strengths. This means that, even at these lower field strengths, it is possible to produce high-quality diagnostic MR images in very acceptable acquisition times.

The combination of lower field strength and deep learning therefore lends itself particularly well to imaging implants using 0.55T systems in clinical routine.

This article will present our experience using a selection of case studies. Full protocols for the hip and knee regions are available on MAGNETOM World: https://www.magnetomworld.siemens-healthineers.com/clinical-corner/protocols

The patients were examined on a 0.55T MAGNETOM Free.Max using only TSE sequences with the WARP option and Deep Resolve reconstruction. The main parameters are presented in the tables. We did not use more advanced WARP techniques such as VAT[1] and SEMAC[2]. Since there were already so few distortions compared to high-field imaging, these techniques offered us no diagnostically relevant advantage that would have justified the disadvantages.

For hip examinations, patients were positioned on their back and head first. The Spine coil and the Contour M/L coil were used for imaging.

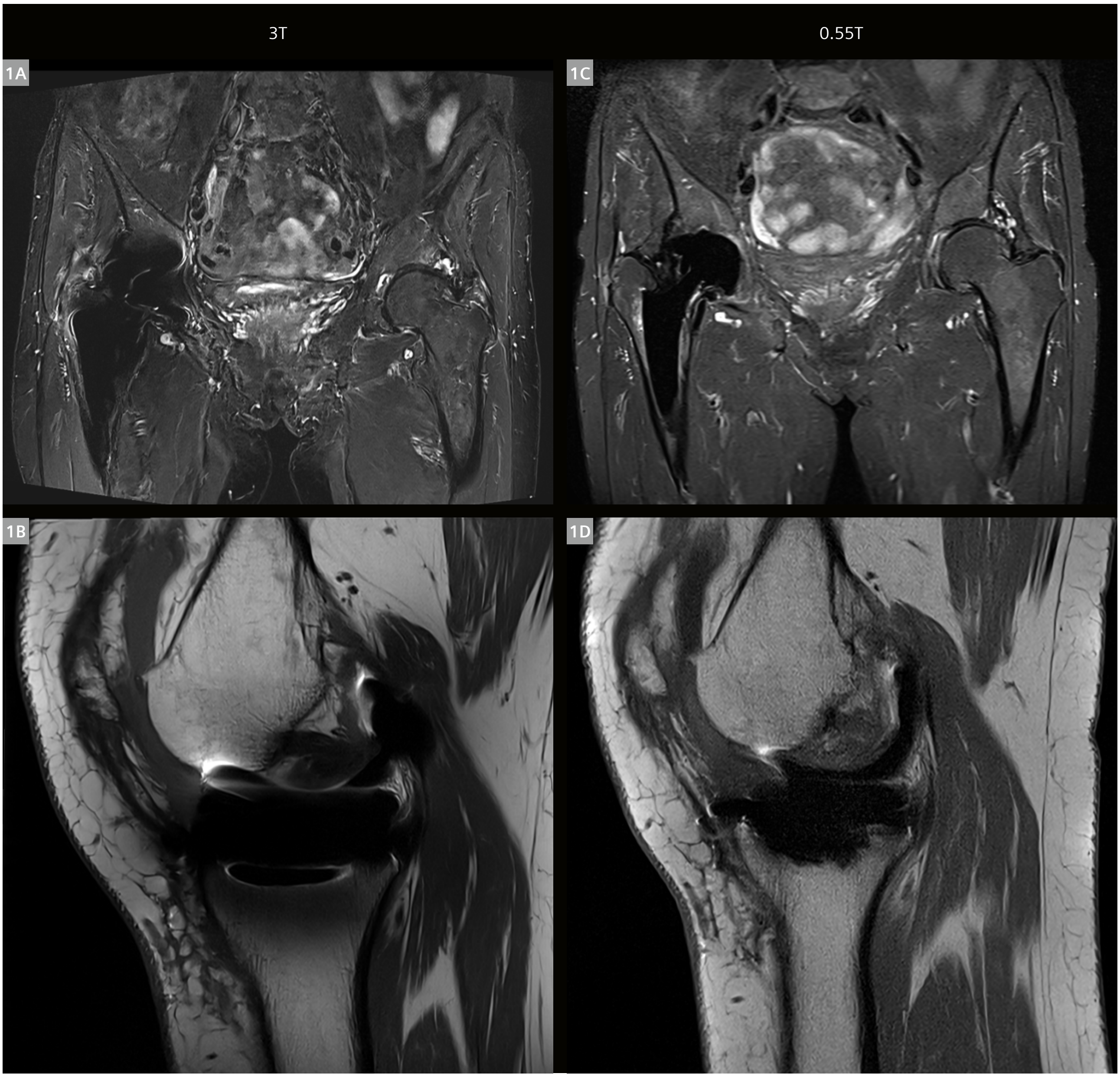
For knee examinations, patients were positioned on their back and feet first. The Contour Knee coil was used for imaging.

[1]View-angle tilting (VAT): Slices are acquired at a tilt angle to partially compensate for the metal distortions. This can cause some blurring, but VAT is essential for the SEMAC technique.

[2]Slice encoding for metal artifact correction (SEMAC): This technique can at least partially correct even very severe distortions. However, it is very time-consuming and therefore generally associated with a loss of resolution and contrast.

The MRI restrictions (if any) of the metal implant must be considered prior to patient undergoing MRI exam. MR imaging of patients with metallic implants brings specific risks. However, certain implants are approved by the governing regulatory bodies to be MR conditionally safe. For such implants, the previously mentioned warning may not be applicable. Please contact the implant manufacturer for the specific conditional information. The conditions for MR safety are the responsibility of the implant manufacturer, not of Siemens Healthineers.

Example images showing the advantage of lower field over high field



1 Left **(1A)** STIR cor and **(1B)** T1 TSE sag on a 3T system. Right **(1C)** STIR cor and **(1D)** T1 TSE sag on a 0.55T system.

Clinical case studies

Knee

Increasing pain after a partial knee replacement. Loosening? A Dual Energy CT scan showed no evidence of loosening. Bone marrow edema of the medial femoral condyle; stress reaction with joint effusion.

2 **(2A)** PD cor. **(2B)** STIR cor, bone marrow edema clearly visible. **(2C)** PD tra.

Knee

Increasing pain following partial knee replacement; establishing cause of pain. An examination on the 3T system was discontinued due to artifacts. Implant appears normal on MRI. Pronounced arthritic changes in the lateral joint cavity, Grade 3 lateral meniscus tear and Grade 4 chondromalacia at the lateral femoral condyle.

3 **(3A)** STIR cor, visible bone marrow edema with arthritic changes. **(3B)** STIR sag, visible bone marrow edema with arthritic changes. **(3C)** PD tra.

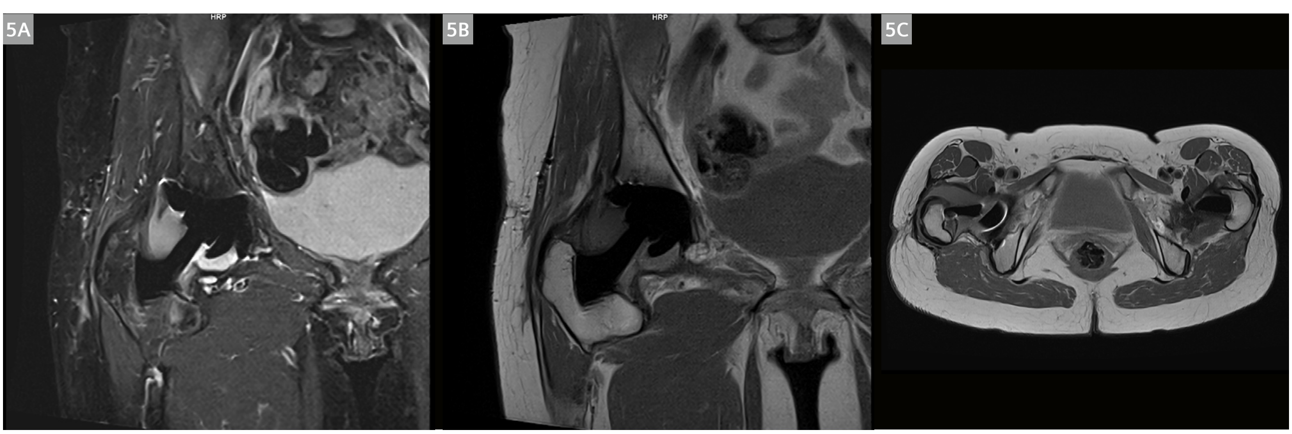
Hip

Pain after implantation of a gamma nail following femoral neck fracture approximately 12 months ago. Material intact. Fracture line still visible with significant soft tissue buildup.

4 **(4A)** T1 cor. **(4B)** STIR cor, clearly visible soft tissue buildup. **(4C)** PD tra, clearly visible fracture line with soft tissue buildup.

Hip

Bilateral total hip replacement followed by recurring dislocation of the right hip prosthesis. Increasing pain in the right hip since falling eight months ago. No fracture, no loosening of the endoprosthesis, no bone lesion. Extensive joint effusion leaking into the trochanteric bursa.



5 **(5A)** STIR cor, clearly visible effusion and hematoma. **(5B)** PD cor. **(5C)** PD tra, clearly visible effusion.

	T1 TSE sag	T1 TSE cor	STIR cor	STIR tra	STIR sag	PD TSE cor	PD TSE tra
Voxel size [mm^3]	0.3 × 0.3 × 3.0	0.3 × 0.3 × 3.0	0.3 × 0.3 × 3.0	0.4 × 0.4 × 4.0	0.4 × 0.4 × 3.0	0.2 × 0.2 × 3.0	0.3 × 0.3 × 3.0
TR/TE [ms]	420 / 8.2	440 / 8.4	3800 / 39	3600 / 39	3500 / 38	2830 / 26	2710 / 25
PE-direction	H>>F	R>>L	R>>L	R>>L	H>>F	R>>L	R>>L
Phase oversampling [%]	150	150	130	200	200	140	150
Avg./Conc.	3 / 2	3 / 2	3 / 2	2 / 2	4 / 1	3 / 1	3 / 1
BW [Hz/px]	305	300	301	300	302	302	300
TA [min]	3:37	3:57	4:43	3:30	3:49	3:03	2:47

Table 1: Scan parameters, knee.

	PD TSE cor	T1 TSE cor	STIR cor
Voxel size [mm^3]	0.5 × 0.5 × 3.0	0.5 × 0.5 × 3.0	0.6 × 0.6 × 3.0
TR/TE [ms]	2500 / 31	386 / 7.2	5000 / 45
PE-direction	R>>L	R>>L	R>>L
Phase oversampling [%]	100	200	200
Avg./Conc.	2 / 1	2 / 2	2 / 1
BW [Hz/px]	395	352	300
TA [min]	2:04	2:26	2:57

Table 2: Scan parameters, bilateral hip.

	PD TSE cor	T1 TSE cor	STIR cor	PD TSE sag	STIR sag
Voxel size [mm^3]	0.5 × 0.5 × 3.0	0.5 × 0.5 × 3.0	0.7 × 0.7 × 3.0	0.5 × 0.5 × 3.0	0.7 × 0.7 × 3.0
TR/TE [ms]	2600 / 24	482 / 8	6100 / 35	3000 / 24	7100 / 35
PE-direction	R>>L	R>>L	R>>L	H>>F	H>>F
Phase oversampling [%]	170	170	200	200	200
Avg./Conc.	2 / 1	2 / 2	2 / 1	2 / 1	2 / 1
BW [Hz/px]	391	349	352	391	352
TA [min]	1:59	2:06	2:46	2:29	3:13

Table 3: Scan parameters, unilateral hip.

Hip

Total hip replacement in 2016. Increasing hip pain for roughly the past three years. Slight bone marrow edema along the stem of the prosthesis, markedly lateral, indicating loosening of the prosthesis.

6 **(6A)** STIR cor, with visible bone marrow edema bordering the implant. **(6B)** PD cor. **(6C)** PD tra.

Conclusion

It has been three and a half years since our MAGNETOM Free.Max was installed, and we see the system as the perfect complement to our high-field scanners (a 3T MAGNETOM Skyra, a 3T MAGNETOM Lumina, a 1.5T MAGNETOM Altea, a 1.5T MAGNETOM Avanto Fit, and our PET/MR scanner, Biograph mMR). Thanks partly to its wide-bore design, our MAGNETOM Free.Max is ideal for examining claustrophobic or extremely overweight patients and is very popular among these populations. Particularly when it comes to examining patients with musculoskeletal implants, we find our lower-field system to be at a great advantage over the high-field systems. This means that diagnosing pathologies following implants is no longer limited to Dual Energy CT scanning: MR imaging can now supply crucial additional information for these cases.

References

1 Feuerriegel GC, Sutter R. Managing hardware-related metal artifacts in MRI: current and evolving techniques. Skeletal Radiol. 2024;53(9):1737–1750.

Contact

Bianca Samsula
ZEMODI - MVZ Zentrum für moderne Diagnostik
Schwachhauser Heerstraße 63a
28211 Bremen
Germany
bianca.samsula@zemodi.de

Markus Lentschig, M.D.
ZEMODI - MVZ Zentrum für moderne Diagnostik
Schwachhauser Heerstraße 63a
28211 Bremen
Germany
markus.lentschig@zemodi.de

Download the 0.55T MAGNETOM Free.Max protocols (**.exar1 and PDF**) at
https://www.magnetomworld.siemens-healthineers.com/clinical-corner/protocols