MRI After Patellofemoral Replacement: the Component–Bone Interface and Rotational Alignment

Thomas J. Heyse, MD · Jens Figiel, MD · Ulrike Hähnlein · Nina Timmesfeld, MSc · Markus D. Schofer, MD · Susanne Fuchs-Winkelmann, MD · Turgay Efe, MD

Received: 5 March 2012/Accepted: 28 March 2013/Published online: 26 June 2013
© Hospital for Special Surgery 2013

Abstract *Background:* In an earlier paper, it was shown that tailored magnetic resonance imaging (MRI) allows for reproducible analysis of the preserved knee joint structures after patellofemoral replacement (PFR). *Purposes:* This pilot study investigates to what degree MRI could produce reliable assessment of the implant–bone interface of femoral and patellar components and rotational alignment following PFR. *Methods:* MRI tailored for reduction of metallic artefacts was performed in seven patients who had undergone PFR. Two independent investigators evaluated the implant–bone interface at femoral and patellar components and the rotational alignment of the femoral component. They also assessed their degree of confidence in evaluation using a five-point scale. The inter-observer reliability was determined. *Results:* Implant-induced MRI artefact was barely observed and there was no interference with component–bone interface evaluation. There was excellent inter-observer reliability, inter-observer

agreement, and confidence for the implant–bone interface at femoral and patellar components and for rotational alignment. The applied score for the interface was found to be reliable. *Conclusion:* Tailored MRI allows reproducible analysis of the implant–bone interface and of rotational alignment of the femoral component in patients who have had PFR. It might prove helpful in the assessment of painful PFR.

Keywords PFR · PFJ · MRI · knee · patellofemoral replacement · component–bone interface

Introduction

Prevalence rates of patellofemoral osteoarthritis range between 9 and 24% in the middle-aged [6, 7] and, although patellofemoral replacement (PFR) is considered viable for end-stage disease [4, 5, 20], results among different surgeons have been variable, also due to the array of devices available [7, 8]. At mid-term follow-up, survival rates of second generation PFRs range from 86 to 94% [1, 3, 10, 14, 16, 19] with the most common reason for revision being progression of tibiofemoral arthritis [1, 14].

Diagnosing knee problems in patients who have had PFR is not straight forward. Although X-rays can be a useful imaging technique, loosening of components may result in radiolucencies at the component–bone interface, osteolysis or subsidence of components. Moreover, both X-rays and computed tomography have only limited sensitivity in detecting loosening and both also expose the patient to ionising radiation. Bone scans are a very sensitive diagnostic tool for component loosening but cannot be considered reliable in the first 2 years after implantation [8, 13]. Magnetic resonance imaging (MRI) remains the gold standard in evaluating painful knees but is generally not considered a useful option after arthroplasty because of the generation of significant metal artefact [21]. MRI tailored to reduce metallic susceptibility artefact has proven to be clinically useful

Level of Evidence: Level IV: Retrospective Case Series.

Electronic supplementary material The online version of this article (doi:10.1007/s11420-013-9336-x) contains supplementary material, which is available to authorized users.

T. J. Heyse, MD (✉) · U. Hähnlein · M. D. Schofer, MD · S. Fuchs-Winkelmann, MD · T. Efe, MD
Department of Orthopedics and Rheumatology,
University Hospital Marburg,
Baldingerstrasse,
35043 Marburg, Germany
e-mail: heyse@med.uni-marburg.de

J. Figiel, MD
Department of Radiology, University Hospital Marburg,
Baldingerstrasse,
35043 Marburg, Germany

N. Timmesfeld, MSc
Institute for Medical Biometry and Epidemiology,
Bunsenstrasse 3,
35037 Marburg, Germany

when used together with traditional imaging techniques in evaluating these patients [17, 21]. To date, there is a lack of research into the use of MRI in diagnosing knee problems in patients who have had PFR.

It is well established that metallic implants cause MRI image artefacts. In contrast, zirconium has a lower magnetic moment [20] and therefore it enables reduction of susceptibility artefact in MRI after total knee arthroplasty (TKA) and allows for evaluation of peri-prosthetic structures [18].

This pilot study investigated to what degree MRI analysis of the component–bone interface and the rotational alignment of the femoral component could be reproduced in patients who had undergone PFR. It was hypothesised that the evaluation would be reproducible.

Material and Methods

The MRI results of the seven patients were subject of this pilot study [12]. Patients had undergone PFR for degenerative joint disease to the patellofemoral compartment of the knee. Patients comprised five women and two men with an average age of 43.6 ± 10.0 years (range 25–55 years) at index PFR (three left, four right knees). MRI was performed at a mean interval of 17.1 ± 10.9 months (range 3–37 months) after the index procedure. The study protocol followed the principles as stated in the declaration of Helsinki. It was reviewed and approved by the local ethics committee.

All patients received the Journey PFR system using cemented femoral zirconium components (Smith & Nephew, Memphis, TN, USA). On the patellar side, cemented full poly patella buttons ($n=5$) were implanted in an inlay technique. The patella remained untouched in two cases. The implants were positioned following the manufacturer's instructions.

During the MRI procedure, patients lay feet first on the scanning table with the extremity fully extended. The MRI examinations were performed on a clinical MRI scanner (MAGNETOM Espree, Siemens Medical Systems, Erlangen, Germany) with a superconducting coil and field strength of 1.5 T. The knee was placed in a transmit–receive extremity coil (CP Extremity, Siemens Medical Systems, Erlangen, Germany). The scans were performed using the perpendicular localizer views (Fig. 1).

Sagittal, axial and coronal turbo spin echo sequences were acquired with a repetition time of 7,000 ms, an echo time of 10 ms, a flip angle of 150° , a slice thickness of 3 mm and a 0.6-mm intersection gap, a 20-cm field of view, a 512×384 -pixel matrix, a pixel bandwidth of 465 Hz/pixel, a 25-echo train length, 384 phase encoding steps and two averages.

We used a score (Table 1) to evaluate the component–bone interface of femoral and patellar components: “0” applied when the interface was not evaluable due to metallic artefacts, “1” applied whenever there was no gap evident between the component and underlying bone; a gap <2 mm corresponded to a score “2” and “3” applied to gaps >2 mm and osteolysis. The interface was divided into regions according to the cuts routinely performed in PFR. On the femoral side, it was differentiated into the proximal, middle and distal third of the interface and subdivided into two

Fig. 1. AP, lateral and merchant views of the knee demonstrate a patellofemoral replacement showing well-fixed components in good position.

sections (lateral and medial) on each. Thus, for each femoral component, we evaluated six zones (Fig. 2). We subdivided the patella into four regions (four zones). In total, we evaluated ten interface zones for each knee. A similar scoring system had been successfully used in a study on TKA [11].

In 1998, Berger et al. developed a technique to quantitatively measure femoral component rotational alignment for TKA using a standard CT scanner [2]. We performed measurements as described in their study: we determined the rotation of the femoral component using the epicondylar axis as a reference. The lateral epicondylar prominence was connected to the middle sulcus of the medial epicondyle. A second line was drawn as a tangent to the femoral implant's dorsal surface of the anterior flange (Fig. 3).

Continuous variables were presented as mean and standard deviation (SD); categorical data were given in absolute figures. For analysis of data, $p < 0.05$ was considered as statistically significant. After verifying a normal distribution of data, values were analysed by Student's *t* test. Two independent investigators (XX. and XX, orthopaedic surgeons with experience in evaluation of MRI following arthroplasty) evaluated the MRI, blinded to the clinical information. We used the intra-class correlation coefficients (ICC) to assess the level of agreement between the observers for femoral rotational alignment. This uses two-way random effects analysis of variance with random observers (ICC (2,

Table 1 A new scoring method was established to assess the interface between PFR components and bone

Interface classification	Gap at interface
0	Artefacts
1	No gap
2	Gap <2 mm
3	Gap >2 mm

1)). The Bland–Altman plot is a useful method of data plotting to represent the agreement between two different observers. It delivers 95% limits of agreement, and thus gives an idea of the range of differences between two measurements of the same specimen.

We used Microsoft Excel (Microsoft Corporation, Seattle, USA) and IBM SPSS Statistics 18 (PASW 18, SPSS Inc., Chicago, IL, USA) to support statistical analysis.

Results

There was excellent inter-observer reliability, as expressed by ICC >0.75 (Table 2), for all interface regions assessed. At the femoral interface, we observed few implant-induced MRI susceptibility artefact problems, resulting in high confidence levels for evaluation. Artefact was no issue on the patellar side, resulting in high reliability, agreement and confidence.

All regions on the femur and patella were evaluable. On the femoral side, 2.4% of the assessed areas showed a gap >2 mm. For the vast majority of regions, there was excellent contact between implant and femoral bone. On the patellar side, 5% of the regions showed gaps <2 mm. All other regions showed excellent contact between implant and patellar bone. The gap analysis showed no correlation to clinically significant findings, since the knees did not present with clinical problems at this time.

For analysis of the rotational alignment of the femoral components (Fig. 3), there was high inter-observer reliability as expressed by a high ICC of 0.993. The Bland–Altman

Fig. 3. Analysis of rotational alignment of the femoral component in a coronal fast spin echo MR: the rotational angle is determined by a *first line* connecting the lateral epicondylar prominence and the middle sulcus of the medial epicondyle, and a *second line* drawn as a tangent to the dorsal surface of the anterior flange of the femoral implant (2.2° of external rotation).

plot revealed a mean difference between observers of -0.29° with a standard deviation of 0.76° and 95% limits of agreement between -1.81 and 1.23° .

Discussion

This pilot study set out to determine to what degree MRI analysis could assess PFR rotational alignment and whether it could be accurately reproduced using a new score to analyse bone–component interface. A previous publication addressed the reproducibility of MRI analysis of preserved anatomic structures of the knee in the same seven patients who had undergone PFR [12].

Our results show that analysis of bone–component interface can be reproduced accurately as demonstrated by high

Fig. 2. This sagittal fast spin echo MR images demonstrates the interface at the femoral and patellar components: **a** no gaps at interface; **b** gaps <2 mm at femoral interface (as pointed out by *arrow*). There were no gaps >2 mm.

Table 2 Inter-observer reliability as expressed by ICC, inter-observer-agreement and the level of confidence for all evaluated structures in MRI after UKA

Structure	ICC	Inter-observer agreement (%)	Confidence
Femur all	0.93	97.6	3.79±0.43
Proximal lateral	1.0	100	3.79±0.43
Middle lateral	1.0	100	3.79±0.43
Distal lateral	1.0	100	3.79±0.43
Proximal medial	0.82	85.7	3.79±0.43
Middle medial	1.0	100	3.79±0.43
Distal medial	1.0	100	3.79±0.43
Patella all	0.91	95	4±0
Proximal lateral	1.0	100	4±0
Distal lateral	1.0	100	4±0
Proximal medial	0.77	80	4±0
Distal medial	1.0	100	4±0

Cohen's kappa for the inter-observer reliability, high confidence levels and high inter-observer agreement. Analysis of zirconium femoral components and patellar implants showed that all interface zones were evaluable. Implant-induced MRI susceptibility artefact, generated by the metallic implants, was barely seen and did not interfere with evaluation.

The data also show that MRI analysis of rotational alignment of femoral implants can be reproduced accurately, as demonstrated by the high ICC for inter-observer reliability and low 95% limits of agreement.

As stated in our previous publication, there were limitations to this study [12]. Group size was small and follow-up studies with more patients are warranted. Reflecting the cost of MRI and patients were not drawn from a specific cohort. Therefore, results in terms of gaps or osteolysis at the interface might not be representative. Future studies with bigger group size could also try to correlate component rotation and gaps at the interface.

Patients in this study had zirconium femoral components, and whether similar results would be expected in patients following PFR with conventional Cobalt–chrome (CoCr) alloy femoral components, may be questionable. CoCr arthroplasties will generate intra-voxel dephasing, limiting evaluation of the interfaces. Zirconium components generate less signal artefact due to zirconium's lower magnetic moment [17, 18] and produced superior results in TKA patients in comparison with conventional implants [11, 18]. We suppose that MRI could also be used as a diagnostic tool after PFR with CoCr femoral components, but there would be greater interference with evaluation of the interface due to signal artefact. Although not commercially available yet, new MRI protocols such as MAVRIC or SEMAC that involve multiple acquisitions slightly offset from the dominant frequency with a recombinant image yielded to decrease artefact may be particularly helpful in the evaluation of CoCr interfaces in the future [9, 11].

From a clinical perspective, these results need to be interpreted with caution. Some gaps at the interface were found in knees that were clinically unremarkable and we cannot justify the diagnosis of a loose component based purely on the results determined by this new scoring system. However, MRI results might be useful in facilitating the complex diagnosis of loosening

and malposition especially within the first 2 years after arthroplasty, when bone scans are often non-diagnostic.

Special protocols are necessary for MRI following TKA. Sofka et al. showed that with an appropriate protocol, MRI allowed evaluation of peri-prosthetic structures such as ligaments, tendons and bone [21]. Further studies are required but there is a growing body of evidence that MRI can have a clinical role to play in post-operative assessment of arthroplasty to the knee. MRI has been useful in evaluating painful or non-functional TKA (arthrofibrosis, synovitis, loosening, chronic infection, osteolysis, particle disease, evaluation of peroneal nerve palsy) [17]. Successful evaluation of radiographically suspected peri-prosthetic osteolysis after TKA has been reported in two small cohorts (11 and 2 patients) [15, 22].

The value of MRI following knee arthroplasty is an important area for future research and our understanding of MRI and its indications are still developing. Further research is necessary to identify suitable indications and to develop algorithms for evaluation. The present study applies a new scoring system that delivers reproducible analysis of component–bone interface that can be done without exposing the patient to radiation. Further work is required to establish whether it might be of benefit in the assessment of suspected loosening of a knee arthroplasty component. Moreover, this technique might prove to be a helpful tool in addressing scientific issues, such as the effect of different cementing techniques, particularly in combination with femoral components made of zirconium.

In conclusion, MRI, performed using a special protocol and a new scoring system, allowed good reproducible analysis of PFR implant–bone interface. Zirconium components generated negligible MRI artefact, resulting in minimal interference with component–bone interface evaluation. MRI, tailored to reduce metallic artefacts, might prove helpful in the diagnosis of component loosening after PFR and for analysis of femoral component alignment.

Acknowledgments The authors would like to thank Hollis Potter, MD, from Hospital for Special Surgery, New York, NY, for her support with establishments of effective MRI protocols. The costs of the MRI were covered by Smith & Nephew, Europe. The sponsor was not involved in acquisition, analysis or interpretation of data.

Disclosures

Conflict of Interest: Thomas J. Heyse, MD received support for travel to meetings for the study or other purposes from Smith & Nephew, Europe; receives payment for lectures including service on speakers' bureaus from Smith & Nephew, Europe, outside the work. Jens Figiel, MD is a paid consultant for Vexim SA, Toulouse, France, outside the work. Markus D. Schofer, MD receives support for travel to meetings for the study or other purposes from Smith & Nephew, Europe; receives payment for lectures including service on speakers' bureaus from Smith & Nephew, Europe, outside the work. Ulrike Hähnlein, Nina Timmesfeld, MSc, Susanne Fuchs-Winkelmann, MD, Turgay Efe, MD have declared that they have no conflict of interest.

Human/Animal Rights: All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2008 (5).

Informed consent: Informed consent was obtained from all patients for being included in the study.

Required Author Forms Disclosure forms provided by the authors are available with the online version of this article.

References

1. Ackroyd CE, Newman JH, Evans R, Eldridge JD, Joslin CC. The Avon patellofemoral arthroplasty: five-year survivorship and functional results. *J Bone Joint Surg Br.* 2007;89(3):310-315.
2. Berger RA, Crossett LS, Jacobs JJ, Rubash HE. Malrotation causing patellofemoral complications after total knee arthroplasty. *Clin Orthop Relat Res.* 1998;356:144-153.
3. Butler JE, Shannon R. Patellofemoral arthroplasty with a custom-fit femoral prosthesis. *Orthopedics.* 2009;32(2):81.
4. Cartier P, Sanouiller JL, Grelsamer R. Patellofemoral arthroplasty. 2-12-year follow-up study. *J Arthroplast.* 1990;5(1):49-55.
5. Cartier P, Sanouiller JL, Khefacha A. Long-term results with the first patellofemoral prosthesis. *Clin Orthop Relat Res.* 2005;436:47-54.
6. Davies AP, Vince AS, Shepstone L, Donell ST, Glasgow MM. The radiologic prevalence of patellofemoral osteoarthritis. *Clin Orthop Relat Res.* 2002;402:206-212.
7. Duncan RC, Hay EM, Saklatvala J, Croft PR. Prevalence of radiographic osteoarthritis—it all depends on your point of view. *Rheumatology (Oxford).* 2006;45(6):757-760.
8. Duus BR, Boeckstyns M, Kjaer L, Stadeager C. Radionuclide scanning after total knee replacement: correlation with pain and radiolucent lines. A prospective study. *Invest Radiol.* 1987;22(11):891-894.
9. Hayter CL, Koff MF, Shah P, Koch KM, Miller TT, Potter HG. MRI after arthroplasty: comparison of MAVRIC and conventional fast spin-echo techniques. *AJR Am J Roentgenol.* 2011;197(3):W405-W411.
10. Hendrix MR, Ackroyd CE, Lonner JH. Revision patellofemoral arthroplasty: three- to seven-year follow-up. *J Arthroplast.* 2008;23(7):977-983.
11. Heyse TJ, Chong LR, Davis J, Boettner F, Haas SB, Potter HG. MRI analysis of the component–bone interface after TKA. *Knee.* 2011;19:290-4.
12. Heyse TJ, Figiel J, Hahnlein U, et al. MRI after patellofemoral replacement: the preserved compartments. *Eur J Radiol.* 2011;81:2313-7.
13. Kantor SG, Schneider R, Insall JN, Becker MW. Radionuclide imaging of asymptomatic versus symptomatic total knee arthroplasties. *Clin Orthop Relat Res.* 1990;260:118-123.
14. Leadbetter WB, Kolisek FR, Levitt RL, et al. Patellofemoral arthroplasty: a multi-centre study with minimum 2-year follow-up. *Int Orthop.* 2009;33(6):1597-1601.
15. Mosher TJ, Davis CM 3rd. Magnetic resonance imaging to evaluate osteolysis around total knee arthroplasty. *J Arthroplast.* 2006;21(3):460-463.
16. Nicol SG, Loveridge JM, Weale AE, Ackroyd CE, Newman JH. Arthritis progression after patellofemoral joint replacement. *Knee.* 2006;13(4):290-295.
17. Potter HG, Foo LF. Magnetic resonance imaging of joint arthroplasty. *Orthop Clin North Am.* 2006;37(3):361-373. vi-vii.
18. Raphael B, Haims AH, Wu JS, Katz LD, White LM, Lynch K. MRI comparison of periprosthetic structures around zirconium knee prostheses and cobalt chrome prostheses. *AJR Am J Roentgenol.* 2006;186(6):1771-1777.
19. Sisto DJ, Sarin VK. Custom patellofemoral arthroplasty of the knee. *J Bone Joint Surg Am.* 2006;88(7):1475-1480.
20. Smith AM, Peckett WR, Butler-Manuel PA, Venu KM, d'Arcy JC. Treatment of patello-femoral arthritis using the Lubinus patello-femoral arthroplasty: a retrospective review. *Knee.* 2002;9(1):27-30.
21. Sofka CM, Potter HG, Figgie M, Laskin R. Magnetic resonance imaging of total knee arthroplasty. *Clin Orthop Relat Res.* 2003;406:129-135.
22. Vessely MB, Frick MA, Oakes D, Wenger DE, Berry DJ. Magnetic resonance imaging with metal suppression for evaluation of periprosthetic osteolysis after total knee arthroplasty. *J Arthroplast.* 2006;21(6):826-831.