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The tibial spine sign does not indicate cartilage damage in the central area of the distal lateral femoral condyle

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Abstract

Purpose A radiographic overlap of the lateral femoral condyle and the lateral tibial spine ('tibial spine sign') might indicate lateral compartment cartilage damage and might be considered a contraindication for unicompartmental knee arthroplasty (UKA). Therefore, the following research questions were asked: (1) does the presence of a 'tibial spine sign' on radiographs correlate with cartilage lesions on the medial aspect of the lateral femoral condyle on corresponding MRIs?; (2) do cartilage lesions on the medial aspect of the lateral femoral condyle indicate cartilage damage in the central area of the distal lateral femur?; and 3) is the 'tibial spine sign' impacted by the degree of varus deformity, the amount of coronal tibiofemoral subluxation or the functional status of the ACL?

Methods One hundred consecutive knees with varus OA in 84 patients were prospectively included. The relationship of the lateral femoral condyle and the tibial spine was graded from 0 to 2 based on the degree of overlap on AP standing knee radiographs. On MRI, cartilage on the medial aspect of the lateral femoral condyle was assessed. Cartilage in the weight-bearing area of the distal lateral femur was analysed according to the OARSI system.

Results The 'tibial spine sign' assessment correlated well with the degree of cartilage damage on the medial aspect of the lateral condyle ($r_s = 0.7$, $p < 0.001$) but did not impact histological OARSI grades in the central weight bearing area of the lateral condyle (n.s.). Mechanical varus and tibiofemoral subluxation were not associated (n.s.) with a positive tibial spine sign. Knees with suggestive ACL insufficiency on MRI had more often a positive tibial spine sign; however, this difference was not statistically significant (n.s.).

Conclusion A positive tibial spine sign does not indicate histologic cartilage damage in the central area of the distal lateral femur and may not be considered a contraindication for medial UKA.

Level of evidence Level III, diagnostic study.

Keywords Unicompartmental knee arthroplasty · Lateral compartment · Cartilage degeneration · Preoperative assessment · Knee radiographs

Introduction

Unicompartmental knee arthroplasty (UKA) is a surgical treatment option for unicompartmental knee osteoarthritis (OA) [12]. There is consensus in the literature that medial UKA requires intact cartilage in the weight-bearing area of the lateral compartment [3, 8]. In varus knee OA, the lateral femoral condyle might impinge on the lateral tibial spine. The resulting overlap of the lateral femoral condyle and the lateral tibial spine can be observed on standing anteroposterior (AP) knee radiographs (Fig. 1). The so-called 'tibial spine sign' may be an indicator for a cartilage lesion on the medial aspect of the lateral femoral condyle. Kendrick et al. reported that such cartilage lesions had no negative effect on the outcome of medial Oxford UKA at a mean follow-up of 4 years [5]. However, intraoperative findings were not correlated with the presence of a tibial spine sign on radiographs, and therefore it remains unclear if the latter is a radiographic sign for lateral compartment cartilage damage.

The study was performed at the Hospital for Special Surgery, New York, USA.

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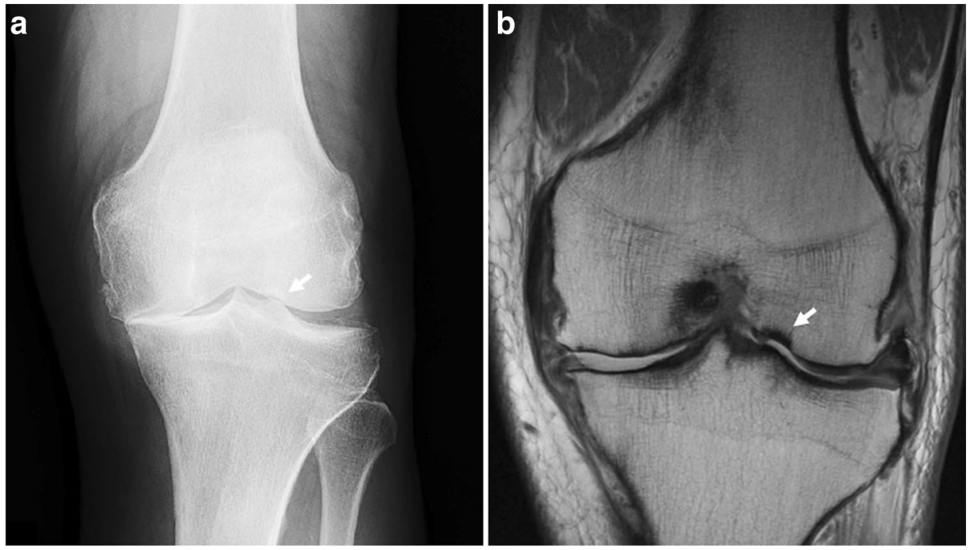

Fig. 1 Positive tibial spine sign on AP standing knee radiograph (**a**); full-thickness cartilage lesion on the medial aspect of the lateral femoral condyle on corresponding MRI (**b**)

The hypothesis of this study was that a radiographic tibial spine sign is not a contraindication for a medial UKA, because it is not associated with inferior cartilage histology in the central area of the distal lateral femur. The following research questions were asked: (1) does the presence of a 'tibial spine sign' on AP knee radiographs correlate with cartilage lesions on the medial aspect of the lateral femoral condyle on corresponding MRIs?; (2) do cartilage lesions on the medial aspect of the lateral femoral condyle indicate cartilage damage in the central area of the distal lateral femur?; and (3) is the 'tibial spine sign' impacted by the degree of varus deformity, the amount of coronal tibiofemoral subluxation or the functional status of the ACL?

Patients and methods

One hundred consecutive knees in 84 patients undergoing primary total knee arthroplasty (TKA) for varus OA between May 2010 and January 2012 were prospectively enrolled in the study.

All patients underwent preoperative hip-to-ankle AP standing radiographs, an AP standing knee radiograph, a lateral knee radiograph, a patella merchant view as well as magnetic resonance imaging of the knee at 1.5 Tesla and 3 Tesla. For AP standing knee radiographs, attention was paid to a strict AP orientation. On hip-to-ankle AP standing radiographs, the hip–knee–ankle angle (HKAA) was defined as the angle between the mechanical axis of the femur (centre of hip to centre of knee) and the mechanical axis of the tibia (centre of knee to centre of ankle) [16]. The lateral knee compartment was assessed on AP radiographs of the knee according to the Kellgren–Lawrence (KL) grading scale [4]. Knees with advanced radiological degeneration in the lateral compartment (> Kellgren–Lawrence grade 2) or cases with missing images or knees with a 1.5 Tesla MRI were excluded, leaving 73 knees (36 females) with mean age of 66 years (SD 9.0; range: 49–87 years) and mean body mass index of 25.6 kg/m^2 (SD 4.8; range 17–37 kg/m^2).

All subjects underwent high-quality preoperative MRI using 3T clinical scanners (GE Healthcare, Waukesha, WI) at the authors' institution using a dedicated knee coil. Patients were positioned in supine position with the knee extended as far as possible. PD TSE sequences were obtained in the axial, coronal and sagittal plane, a PD TSE FS sequence in the sagittal plane, respectively.

On calibrated AP standing knee radiographs, the overlap of the lateral femoral condyle and the lateral tibial spine was evaluated. For a tibial spine assessment, a grading scale from 0 to 2 was established (Fig. 2). Furthermore, the amount of coronal tibiofemoral subluxation was assessed in millimeters utilizing a validated method [14]. Subluxation was measured at the articular plane. Two lines perpendicular to the ground were drawn at the most lateral articular margins of the lateral femoral condyle and the lateral tibial plateau without considering possible osteophytes. The distance between the lines was subsequently measured.

On preoperative MRI, the condition of cartilage on the medial aspect of the distal lateral femur was assessed in the sagittal and coronal plane according to the maps provided by the International Cartilage Repair Society [1]. A modified Outerbridge grading scale was used for a standardized cartilage assessment [10]. Grade 0 indicated intact cartilage without notable defects, grade 1 cartilage softening with fibrillation and superficial fissures, grade 2 defects that extended less than 50%, grade 3 deep lesions that extended more than 50% of the cartilage thickness and grade 4 full-thickness cartilage loss, respectively. Grade 0–2 cartilage lesions were considered mild changes, grade 3 and 4 lesions severe cartilage alterations, respectively. MRIs were evaluated by a

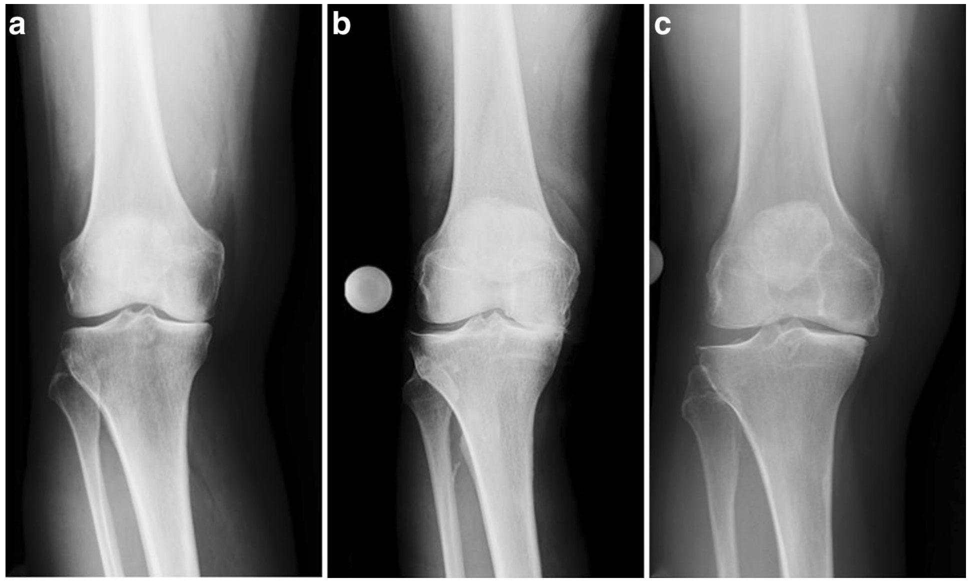

Fig. 2 Tibial spine sign assessment on AP standing knee radiographs: **a** Grade 1: the lateral femoral condyle does not touch the lateral tibial spine. **b** Grade 1: the lateral femoral condyle touches the lateral tibial spine. **c** Grade 2: Overlap of the lateral femoral condyle and the lateral tibial spine 2 (i.e. positive tibial spine sign)

research fellow (WW) with 8 years of experience in assessing knee MRIs.

The structural integrity of the ACL was assessed on MRI and graded as intact, with degenerative changes or completely torn [2]. The group of ACLs with degenerative changes included thinning, scarring, ganglion formation, mucoid degeneration or partial ACL tears [15]. The ACL assessment was based on the report of a blinded board-certified radiologist with extensive experience in musculoskeletal MRI. The amount of intact posterior tibial cartilage (L_{POST}) in the medial compartment was evaluated on sagittal images as previously reported [17]. Knees with signs of ACL degeneration and an $L_{POST} < 14\%$ were considered as functionally insufficient. The latter and torn ACLs were defined as knees with suggestive ACL insufficiency. Knees with an intact ACL and knees with ACL degeneration but an $L_{POST} \geq 14\%$ were considered as having a functionally intact ACL [17].

All TKAs were performed by one experienced surgeon (FB) performing more than 500 arthroplasties per year using a standard medial parapatellar approach. An 8 mm diameter osteochondral plug was harvested from the central distal lateral femur using an osteochondral autograft transfer system (OATS) harvester (Arthex, Naples, FL, USA). Harvesting was performed according to the manufacturer's instructions. The harvester was placed perpendicular to the surface and advanced through the cartilage and into bone. The harvester was twisted clockwise 90° under pressure, back, and then a full clockwise revolution was performed. The harvester was withdrawn containing the osteochondral sample. The osteochondral samples were immediately placed in protease inhibitor (Sigma-Aldrich, St Louis, MO, USA) and stored at − 20 °C. The histological analysis was performed according to the validated osteoarthritis cartilage histopathology assessment system (OARSI histological system) [11, 18]. All sections were scored in consensus by an experienced, board-certified pathologist and a trained research fellow (WW).

Intra-observer and inter-observer reliabilities for measurements were assessed by two independent blinded observers for 20 randomly selected corresponding sets of radiographs, MRIs and histological samples. For intra-observer reliabilities, grading and measurements were performed at two occasions separated by a minimum of 4 weeks. Single measures are given for intra-observer calculations and average measures for the inter-observer calculations.

Excellent inter- and intra-observer ICCs were observed for measurements of HKAA (inter: 1.0; intra: 1.0), excellent intra-observer ICC for the OARSI system (0.9), excellent inter-observer ICCs for medial lateral femoral condyle cartilage (0.9), tibial spine sign assessment (0.9) and measurement of coronal tibiofemoral subluxation (1.0), respectively.

The study was approved by the Hospital for Special Surgery Institutional Review Board (#29023) and has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. All patients signed an informed consent.

The distribution of all variables was examined in exploratory data analyses and tested for normality using the Kolmogorov–Smirnov test. As not all variables met the criteria for normal distribution, the Mann–Whitney *U* test or the Kruskal–Wallis test was used to compare the distribution of variables. The nonparametric Spearman rank correlation coefficient (r_s) was calculated. The standard deviation and range were stated. Power analysis was performed in G-power (G*Power Version 3.1.9; University of Dusseldorf, Germany) for the Mann–Whitney U test using an alpha of 0.05, a power of 80% and an effect size of 0.3 resulting in a sample size of 64. Statistical tests were performed using SPSS Version 26 software for Mac (SPSS Inc, Chicago, IL, USA). All statistical tests were two sided with statistical significance set at $\alpha = 0.05$.

Results

The lateral compartment was graded as KL grade 0 in 2 out of 73 knees (3%), as grade 1 in 30 knees (41%) and as grade 2 in 41 knees (56%), respectively. The mean HKAA was 8.6° (SD 4.0, range 1–19) and the mean coronal tibiofemoral subluxation was 4.8 mm (SD 1.5; range 2–11). Tibial spine sign assessment revealed grade 0 in 42 knees (58%), grade 1 in 11 (15%) knees and grade 2 in 20 (27%) knees, respectively. The grading of cartilage defects of the medial aspect of the distal lateral femoral condyle on MRI revealed grade 1 in 7 knees (10%), grade 2 in 31 knees (42%), grade 3 in 19 knees (26%) and grade 4 in 16 knees (22%), respectively. In case of severe cartilage damage (grade 3 and 4), a mean defect length of 9.0 mm (SD 3.7; range 4–19) and a mean defect width of 5.0 mm (SD 2.7; range 1–13) were measured. The ACL was intact in 19 knees (grade 1; 26%), degenerated with $L_{POST} \geq 14\%$ in 41 knees (grade 2; 56%), degenerated with $L_{POST} < 14\%$ in 6 knees (grade 3; 8%) and torn in 7 knees (grade 4; 10%), respectively. The MRI was suggestive of an ACL insufficiency in 13 knees (grade 3 and 4).

A good correlation ($r_s = 0.7$, $p < 0.001$) of the tibial spine assessment and the condition of cartilage of the medial aspect of the lateral femoral condyle on MRI was observed. In knees with a positive tibial spine sign (grade 2), corresponding MRIs revealed severe cartilage lesions in 90% (18/20) of all cases [grade 3: 4/20 cases (20%), grade 4: 14/20 cases (70%)].

The distribution of histological OARSI grades in the central area of the distal lateral femur was independent (n.s.) of the presence of cartilage damage on the medial aspect of the distal lateral femur.

The tibial spine sign was not associated (n.s.) with the degree of mechanical varus and the amount of coronal tibiofemoral subluxation. Knees with suggestive ACL insufficiency on MRI had more often a positive tibial spine sign (ACL insufficiency: 54% vs ACL functionally intact: 23%); however, this difference was not statistically significant (n.s.). There was also no correlation ($r_s = -1.4$, n.s.) of varus deformity and coronal tibiofemoral subluxation.

Discussion

The most important finding of the current study is that a positive tibial spine sign on radiographs does not indicate cartilage damage in the central area of the distal lateral femur.

In the majority of knees with a positive tibial spine sign on AP standing radiographs, advanced cartilage lesions on the medial aspect of the lateral femoral condyle were observed on MRI. The literature provides limited data on the prevalence of cartilage lesions on the medial aspect of the lateral femoral condyle and its implications for the longevity of medial UKA. Kendrick et al. published on intraoperatively observed damage to the cartilage on the medial side of the lateral condyle during implantation of an Oxford UKA [5]. The authors observed partial or full-thickness defects on the medial wall of the lateral condyle in only 10.3% of varus knees. This is in contrast to the current study reporting grade 3 and 4 cartilage lesions on MRI in 48% of the cases. The current study enrolled knees with more advanced varus OA and systematically assessed the medial aspect of the femoral condyle on MRI, whereas Kendrick's study reported such lesions only as concomitant intraoperative findings. This might explain why such cartilage lesions were more common in the current study. Although Kendrick et al. did not measure the defect size, they described them as 'long and narrow' which is similar to the findings in this study.

The findings of the current study support the concept of intraarticular mechanical impingement of the femoral condyle on the tibial spine as the cause for cartilage lesions on the medial aspect of the lateral femoral condyle. In selected cases, such cartilage defects—even if they are full thickness—might therefore not be considered a contraindication for medial UKA.

The aetiology of lateral femoral condyle impingement on the lateral tibial spine remains controversial. It has been suggested that for such cartilage lesions to appear on the medial side of the lateral condyle there has to be substantial varus deformity and coronal tibiofemoral subluxation [5]. However, the current analysis was unable to identify differences of mechanical varus and coronal tibiofemoral subluxation in knees with or without radiographic tibial spine impingement. In addition, varus deformity did not correlate with tibiofemoral subluxation. We are not aware of any study that has investigated the association of a positive tibial spine sign with varus deformity and coronal tibiofemoral subluxation. Our findings might indirectly be supported by Nam et al. who suggested tibiofemoral subluxation as a variable independent of mechanical alignment [9]. Tibiofemoral subluxation is commonly observed in varus OA of the knee and may exacerbate tibiofemoral incongruence which in the presence of a prominent tibial spine causes impingement on the femoral condyle. However, the morphology of the lateral tibial spine appears to be heterogeneous so that a direct correlation of coronal tibiofemoral subluxation as well as advanced varus deformity with tibial spinal impingement cannot be detected.

A tendency towards a positive tibial spine sign in knees with ACL insufficiency was observed. However, based on the numbers available, no statistically significant difference in the tibial spine sign assessment was detected between knees with a functionally intact ACL and ACL insufficiency. The functional integrity of the ACL is considered an essential requirement for UKA [3]. Higher failure rates have been reported for UKA in patients with an insufficient ACL at the time of surgery [6, 7]. In the work-up for medial UKA, the knee should therefore be assessed for sagittal instability in case of a positive tibial spine sign.

The current study has the following limitations: (1) it remains unclear whether excellent long-term outcomes would have been observed following UKA implantation, since all patients underwent a TKA instead of a UKA. (2) Cartilage lesions on the medial aspect of the lateral femoral condyle were not assessed during surgery. The results of this study are based on an MRI cartilage assessment. However, it has been demonstrated that especially advanced cartilage lesions can be detected on MRI with high accuracy [13]. (3) Malrotation of AP knee radiographs may result in a false-positive tibial spine sign. Therefore, attention should be paid to obtain knee radiographs in a strict AP orientation. The good correlation of the tibial spine sign assessment and MRIs indicate that the rotation of knee radiographs was well controlled in the current study. (4) All patients in the present study received a TKA instead of UKA. Therefore, not all patients may have met the preoperative criteria for a medial UKA with regard to deformity or functional integrity of the ACL.

The current study is of clinical relevance for surgeons performing medial UKA. It confirms that even though a full-thickness cartilage lesion is observed on the medial aspect of the lateral femoral condyle during surgery, the surgeon does not have to be concerned about inferior cartilage histology in the central area of the distal lateral femur.

Conclusion

The presence of a positive tibial spine sign on AP standing radiographs is associated with advanced cartilage lesions on the medial aspect of the lateral femoral condyle on MRI in 90% of knees. However, such advanced cartilage defects do not indicate cartilage damage in the central area of the distal lateral femur.

Authors' contribution WW and FB prepared the manuscript and coordinated to the study. BS performed the statistical analysis and radiographic assessments. RW made substantial contributions to the conception of the manuscript and the interpretation of data. FB conceived of the study and was responsible for the study design and the inclusion of patients. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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Ethical approval The study was approved by the institutional ethics committee and has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments.

Informed consent All patients gave informed consent prior to inclusion in the study.

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