Acta Medica Okayama

Volume 60, *Issue* 4 2006 *Article* 1

AUGUST 2006

The correlation between magnetic resonance detected cartilage defects and spiking of tibial tubercles in osteoarthritis of the knee joint.

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Abstract

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KEYWORDS: osteoarthritis, tubercles (of the intercondylar eminence), spiking, magnetic resonance imaging

*PMID: 16943857 [PubMed - indexed for MEDLINE]

Acta Med. Okayama, 2006
Vol. 60, No. 4, pp. 207-214

Acta Medica Okayama
http://www.lib.okayama-u.ac.jp/www/acta/

Original Article

The Correlation between Magnetic Resonance Detected Cartilage Defects and Spiking of Tibial Tubercles in Osteoarthritis of the Knee Joint

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The aim of the study was to ascertain whether spiking of the tibial tubercle is associated with cartilage defects detected by magnetic resonance imaging (MRI) in patients with osteoarthritis (OA) of the knee joint. Angulation of the tip of the medial and lateral tubercles, and the height of the tubercles above the tibial plateau were measured on a standard anteroposterior radiograph of the knee joint. Cartilage defects in the tibiofemoral joint (TFJ) were determined by MRI examination. The lengthening and sharpening of the angles of the tubercles were significantly more prominent in the patients than controls. A strong association was found between angulation (if less than 70°) and especially the height (if more than 0.16) of the medial tibial spike and MRI-detected cartilage defects in the medial tibiofemoral compartment. The predictive value of the spiking of tibial tubercles for MRI-detected cartilage defects in TFJ is related to the degree and size of the spiking. The presence of tibial spiking itself may not be a reliable sign of early OA.

Key words: osteoarthritis, tubercles (of the intercondylar eminence), spiking, magnetic resonance imaging

Osteoarthritis (OA) is a multifactorial disease with a focal loss of articular cartilage with variable underlying bone reaction. Plain film radiographs are widely used to diagnose and quantify disease progression in OA. However, a plain radiograph is inadequate for assessing the loss of articular cartilage, a hallmark of OA, in detail.

MRI, with its good tissue contrast and anatomical resolution, provides a non invasive examination tool of the TFJ in early stages of OA, for detection of cartilage defects [1-3]. MRI is considered to be an accurate means of detecting and staging moderate and advanced cartilage lesions in the knee joint and is thus useful in the evaluation of knee OA [1, 4-6]. In this regard MRI offers a definite advantage to plain film radiographs. A major drawback of MRI is the expensive and time-consuming imaging procedure for routine diagnostic use.

It has been stated in radiological texts that "spiking" or angulation of the tibial tubercles (tibial spines, intercondylar eminences) is an early sign of OA of the knee joint [7, 8]. But Donnelly *et al.* [9] have suggested that isolated tibial spiking is not a reliable marker of the presence of knee OA and should not routinely be reported. If there is a relationship between bone and cartilage changes, MRI

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would detail actual articular cartilage loss as assessed indirectly by tibial spiking on X-rays in OA of the knee. A strong association between marginal osteophytes and MRI-detected cartilage defects has been confirmed by previously studies [1, 10]. Boegard *et al.* [1] found no relation between the presence of central osteophytes and MRI-detected cartilage lesions in the TFJ. Their study, however, had some shortcomings such as no evaluation for angulations of the central osteophytes.

The aim of the present study was to ascertain whether spiking of the tibial tubercle reflects MRI-detected cartilage defects in the knee.

Materials and Methods

Seventy-six knees of 47 patients with symptomatic TFJ OA of the knee joint were enrolled in the study (male: 8, female: 39, mean age 58.5 ± 8.4 yr (range 45–75 yr)). The minimum age for entry into the study was 45 years. Participants in the study were considered to have knee OA symptoms if they answered in the affirmative to the question "over the past 4 weeks have you had pain, aching, or stiffness in one or both knees on most days?" [11]. The individual answering positively to the question was eligible for recruitment as a person with knee pain. The control group consisted of 31 knees of 16 volunteer subjects with neither symptoms nor history of knee problems. Control subjects were recruited to achieve similarity of mean age, age range, and sex distribution (male: 4, female: 12, mean age 59.1 ± 9.8 yr (range 46–77 yr)). Body mass index values were also similar in patients and control groups (30.0 ± 4.1 kg/m^2 vs 28.2 ± 3.7 kg/m^2, p: 0.13). The physical examination of the knees in all control subjects was normal. Individuals with total knee replacements, with rheumatoid arthritis, or other forms of arthritis were excluded from the study.

Standard weight-bearing anteroposterior radiographs of both knees in the fully extended position were obtained from all subjects. Radiographic severity was measured by Kellgren-Lawrence (K-L) grade (0–4) on anteroposterior view only at each tibiofemoral compartment (for which reproducibility has been reported) [12]. The highest OA grade (either knee) was designated as the OA grade for that particular subject. Radiographic OA of the TFJ was defined as the presence of definite osteophytess (K-L grade 2 or more) in a knee at any of the compartments by a radiologist who was unaware of the clinical information. Symptomatic primary OA of the TFJ was defined as the presence of knee symptoms in a patient with ipsilateral radiographic evidence of OA [11]. This definition meets American College of Rheumatology criteria for the knee OA [13]. Conventional radiographs of the knees in the control group showed no definite osteophytess, including the patella.

The radiograms were evaluated for osteophytes at the medial and lateral tibial and femoral condyles (defined as marginal osteophytes) into 4 grades (0–3) according to Boegard *et al.* [1].

Two sets of measurements were obtained for each tubercle of the intercondylar eminence of the tibial plateau on a standard antero-posterior radiograph of the knee joint, as described previously [9, 14]. Lines were drawn at a tangent to the tips of the tubercles on either side, intersecting at the tip of the tubercle, and the angle between these lines was measured. The ratio of the height of each tubercle above the tibial plateau to the overall width of the tibial plateau was calculated. This measurement allowed correction for individual variation in tibial size. The angulation and height of the tibial tubercles were measured as hypersharpening of the tip of the spine in a vertical direction, rather than as medial or lateral displacement of the tip of the spine. All measurements were assessed by a radiologist (ST) and a clinician (ZU) together. There was complete agreement between the examiners on the measurements.

MRI was obtained for both knees of all subjects, except for 4 knees in patient and 3 knees in control groups due to various reasons. All studies were performed on a Gyroscan Panorama 0.23 Tesla Open MRI System (Philips Medical Systems, Helsinki, Finland), using a phased array knee coil. An anchoring device was used for the ankle and knee to ensure a uniform position between subjects. The imaging protocol included sagittal and coronal fast spin echo proton density and T2 weighted images (TR 3000, TE 22/110) with a slice thickness of 4.5 mm, a 0.5 mm interslice gap, 2 NEX, field of view 20–25 cm, a matrix of 256×256, and an echo- train length of 4.

MRI studies from the study subjects and controls were mixed and interpreted blindly by a radiologist experienced in musculoskeletal MRI approximately 3 months after the end of the study. The MRI examinations were assessed for cartilage defects in each of the articular surfaces of the TFJ in sagittal and coronal planes. The defects were graded: as absent (grade 0); as $\leq 50\%$ reduction of the cartilage thickness (grade 1); as $> 50\%$ reduction of the cartilage thickness (grade 2); and as involving bone loss (grade 3) [1]. The worst score observed in any one of the planes was accepted as a grade of cartilage defects of that joint.

Statistical analysis; statistical analysis was performed with the SPSS package. Analysis of statistical correlation was performed by the Spearman test of rank correlation in the patients with TFJ OA. The correlation between marginal osteophytes, MRI-detected cartilage defects and K-L score, and tibial spiking was searched. In addition, the correlation between MRI-detected cartilage defects in the TFJ and tibial spiking was determined in the controls. The Mann-Whitney U-test was used to analyze differences between the groups and the differences between the tibial and femoral condyles with respect to the osteophytes and MRI-detected cartilage defects in patients with TFJ OA. The MRI-detected cartilage defect between the reference subjects and patients with TFJ OA was analyzed by the chi-square test. $p < 0.05\%$ was established as a level of significance. Sensitivity, specificity, and positive predictive values were used in a validation assessment of tibial spiking compared with MRI diagnosis in patients with TFJ OA. The sensitivity of a test is defined as the percentage of persons with a disease of interest that has positive test results. Specificity is defined as the percentage of persons without the disease of interest who have negative test results. The positive predictive value is defined as the percentage of persons with positive test results who actually have the disease of interest [15].

Results

Twenty-nine patients had bilateral and 18 had unilateral TFJ OA. There was a significant reduction in spike angulation and increase in spike height in patients with TFJ OA when compared to controls ($p < 0.05$, Table 1).

More osteophytes were found at the tibial condyles, particularly in the lateral condyle, than femoral condyles. But there was no significant difference between the femoral and tibial condyles (medial condyles p: 0.20, lateral condyles p: 0.25). The most affected joint surface was the medial femoral condyle, where 67 (93%) knees with cartilage defects were registered (Table 2). The difference was not significant for the femoral condyles compared with the tibial condyles (medial condyles p: 0.61, lateral condyles p: 0.91). Parallel cartilage defects were considered in the femoral and tibial cartilages in both the medial and lateral tibiofemoral compartments, mostly grade 1 and less grade 2 on MRI in the control subjects (24 knees (82.8%) in medial, 21 knees (72.4%) in the lateral tibiofemoral compartment). There were no consistent differences in cartilage defects between the patients with TFJ OA and controls.

Table 1 Comparison of tibial spike angulation and height in the groups

	TFJ (76 K)	Control (31 K)	TFJ-C (*p* value)
M°	102.1 (19.4) <40–145>	112.3 (21.6) <70–140>	*0.02
L°	105.6 (23.6) <46–150>	121.5 (18.2) <90–156>	*0.006
MH	0.12 (1.9) <0.08–0.17>	0.11 (1.4) <0.10–0.15>	*0.04
LH	0.11 (2.0) <0.06–0.17>	0.10 (1.4) <0.08–0.14>	*0.008

Values in parentheses are (SD), <minimum-maximum>
TFJ, The patients with tibiofemoral joint osteoarthritis; M°, Medial spike angle; L°, Lateral spike angle; MH, Medial spike height; LH, Lateral spike height; C, Controls; K, Knees.
*: Statistically significant difference between the groups.

Table 2 The number (%) of knees in patients with TFJ OA for presence of osteophytes and cartilage defects.

	Osteophytes (n: 76 knees)	Cartilage defects (n: 72 knees)
Medial femur	43 (56.5)	67 (93.0)
Medial tibia	53 (69.7)	64 (88.8)
Lateral femur	56 (73.6)	58 (80.5)
Lateral tibia	64 (84.2)	57 (79.1)

Table 3 shows correlations between marginal osteophytes and MRI-detected cartilage defects in the TFJ and tibial spiking in patients with TFJ OA. Lateral spike angulation showed a correlation with osteophytes at the medial tibial condyle, but not those at the lateral tibiofemoral compartment, and the lateral spike height was associated with osteophytes in the lateral tibial condyle. There was a strong association between the medial spike height and MRI-detected cartilage defects in the medial tibiofemoral compartment. The correlation between the lateral spike height and MRI-detected cartilage defects in the lateral femoral condyle was weak. Lateral spike height also showed a correlation with K-L score only at the lateral tibiofemoral compartment (r: 0.23, p: 0.04). Table 4 shows correlations between MRI-detected cartilage defects in the TFJ and tibial spiking in the controls. In contrast, in patients the cartilage defects correlated inversely with tibial spiking.

For MRI-detected cartilage defects in the TFJ, the sensitivity, specificity, and positive and negative predictive values for different values of tibial spiking were calculated in patients with TFJ OA (Table 5 and 6). Medial spike angulation of 70 degrees and less and a height of 0.16 or more had a specificity and a positive predictive value of 100% and 100% respectively for MRI-detected cartilage defects of both the medial femoral and tibial condyle, while the sensitivity was in general low. Also, medial spike heights of 0.14 or more had a specificity and a positive predictive value of 100% and 100%, respectively for MRI-detected cartilage defects in the medial femoral condyle, while the sensitivity and negative predictive value were 16.4% and 8.2%, respectively. Tibial spiking at the medial tubercles had more specificity and a higher positive predictive value than lateral tubercules for MRI-detected cartilage defects in knees. However, for lateral spike angulation, the specificity and positive predictive value for cartilage defects at both the lateral femoral and tibial condyles were high. In general, the specificity and positive predictive values for the medial spike height were higher than angulation in the same spike. The specificity and positive predictive values for 70-degree lateral spike angulation were higher

Table 3 The correlation between marginal osteophytes and MRI-detected cartilage defects in the tibiofemoral joint and tibial spiking in patients with TFJ OA (Correlation (R))

	Medial spike angle	Lateral spike angle	Medial spike height	Lateral spike height
Osteophyte medial femur	−0.07 (p: 0.53)	−0.12 (p: 0.28)	0.15 (p: 0.19)	0.07 (p: 0.53)
Osteophyte medial tibia	−0.18 (p: 0.11)	−0.26 (p: 0.02*)	0.10 (p: 0.38)	0.16 (p: 0.14)
Osteophyte lateral femur	−0.08 (p: 0.46)	−0.13 (p: 0.24)	−0.13 (p: 0.24)	0.06 (p: 0.58)
Osteophyte lateral tibia	−0.06 (p: 0.60)	−0.08 (p: 0.45)	−0.02 (p: 0.84)	0.23 (p: 0.04*)
Cartilage defect medial femur	−0.002 (p: 0.98)	−0.02 (p: 0.86)	0.29 (p: 0.01*)	0.01 (p: 0.89)
Cartilage defect medial tibia	−0.04 (p: 0.68)	−0.01 (p: 0.93)	0.35 (p: 0.002*)	0.13 (p: 0.27)
Cartilage defect lateral femur	0.03 (p: 0.75)	−0.04 (p: 0.68)	0.15 (p: 0.20)	0.23 (p: 0.04*)
Cartilage defect lateral tibia	0.06 (p: 0.58)	0.10 (p: 0.38)	0.16 (p: 0.17)	0.20 (p: 0.08)

*: Statistically significant correlation.

Table 4 The correlation between MRI-detected cartilage defects in the tibiofemoral joint and tibial spiking in the controls (Correlation (R))

	Medial spike angle	Lateral spike angle	Medial spike height	Lateral spike height
Cartilage defect medial femur	0.39 (p: 0.03*)	0.09 (p: 0.62)	−0.36 (p: 0.05)	0.05 (p: 0.78)
Cartilage defect medial tibia	0.34 (p: 0.06)	0.03 (p: 0.84)	−0.42 (p: 0.02*)	−0.04 (p: 0.83)
Cartilage defect lateral femur	−0.13 (p: 0.47)	−0.00 (p: 0.96)	−0.45 (p: 0.01*)	−0.43 (p: 0.01*)
Cartilage defect lateral tibia	−0.13 (p: 0.47)	−0.00 (p: 0.96)	−0.45 (p: 0.01*)	−0.43 (p: 0.01*)

*: Statistically significant correlation.

than heights in the same spike.

Discussion

The evaluation of cartilage lesions in OA is important since they might be related to disease progression. Routine radiographic imaging makes it possible to assess bone changes. It is impossible to demonstrate cartilage lesions with these radiographs. However, if a correlation between bone and cartilage lesions could be demonstrated, it could also provide information about the cartilage lesions. In the present study, a significant association was found between the medial spike height and MRI-detected cartilage defects in the medial tibiofemoral compartment. We also found a correlation between the lateral spike height and MRI-detected cartilage defects at the lateral femoral condyle. These results could be explained by OA in the knee joint primarily affecting the medial tibiofemoral compartment and MRI-detected cartilage defects being found more commonly at the femoral condyles. Boegard *et al.* [1] have further emphasized the significance of marginal osteophytes in the TFJ as a sign of MRI-detected cartilage defects in the same joint. But they found no relation between the presence of central osteophytes and MRI-detected cartilage lesions in the TFJ. In this study patients were chosen after exclusion of those having OA with obliteration of the joint space or bone attrition.

While the spiking at the tubercles was increasing (if the angulation was less than 70°), the specificity and positive predictive value of spiking of the medial and lateral (for angulation) tibial tubercles were increased to 100% and to almost 100% for MRI-detected cartilage defects anywhere in the joint. We also found that the predictive value of lengthening at the medial tubercles (height is more than 0.16) is considerably high for MRI-detected cartilage defects at the medial tibiofemoral compartment.

However, decreases in the tibial spiking values were also found to have a very high positive predictive value (almost 80%–90%) for MRI-detected cartilage defects, while the specificity decreased considerably (Table 5, 6). These findings further emphasize the significance of prominent spiking of the tibial tubercles as a sign of MRI-detected cartilage defects in the OA of the TFJ (Fig. 1). But the predictive value of the tibial spiking for MRI-detected cartilage defects was considerably low. Therefore, variable lower values of tibial spiking seem to not be usable for clinical or epidemiological purposes in the TFJ as indicators of MRI-detected cartilage defects. Some cases may not have cartilage defects but have moderate spiking (Fig. 2). Furthermore there might be cases with no spiking of the tibial tubercles but

Table 5 The sensitivity, specificity, and positive predictive value (PV) of different tibial spike angulation for MRI-detected cartilage defects in the TFJ. Data are shown as percentages.

MS°	Cartilage defect medial femur			Cartilage defect medial tibia		
	Sensitiv.	Specific.	(+)PV	Sensitiv.	Specific.	(+)PV
70°	10.4	100.0	100.0	10.9	100.0	100.0
90°	22.4	50.0	88.9	23.4	71.4	88.2
110°	70.1	25.0	94.0	70.3	28.6	90.0
130°	94.0	–	94.0	93.8	–	89.6
LS°	**Cartilage defect lateral femur**			**Cartilage defect lateral tibia**		
	Sensitiv.	Specific.	(+)PV	Sensitiv.	Specific.	(+)PV
70°	13.8	92.9	88.9	14.0	93.3	88.9
90°	25.9	78.6	83.3	24.6	73.3	77.8
110°	55.2	57.1	84.2	52.6	46.7	78.9
130°	89.7	14.3	81.3	89.5	13.3	79.7

MS°, Medial spike angle; LS°, Lateral spike angle.

Table 6 The sensitivity, specificity, and positive predictive value (PV) of different tibial spike heights for MRI-detected cartilage defects in the TFJ. Data are shown as percentages.

MH	Cartilage defect medial femur			Cartilage defect medial tibia		
	Sensitiv.	Specific.	(+)PV	Sensitiv.	Specific.	(+)PV
0.10	83.6	20.0	93.3	84.4	25.0	90.0
0.12	53.7	80.0	97.3	54.7	75.0	94.6
0.14	16.4	100.0	100.0	15.6	87.5	90.9
0.16	4.5	100.0	100.0	4.7	100.0	100.0
LH	**Cartilage defect lateral femur**			**Cartilage defect lateral tibia**		
	Sensitiv.	Specific.	(+)PV	Sensitiv.	Specific.	(+)PV
0.08	94.8	14.3	82.1	93.0	6.7	79.1
0.10	74.1	50.0	86.0	73.7	46.7	84.0
0.12	36.2	78.6	87.5	36.8	80.0	87.5
0.14	5.2	85.7	60.0	5.3	86.7	60.0

MH, Medial spike height; LH, Lateral spike height.

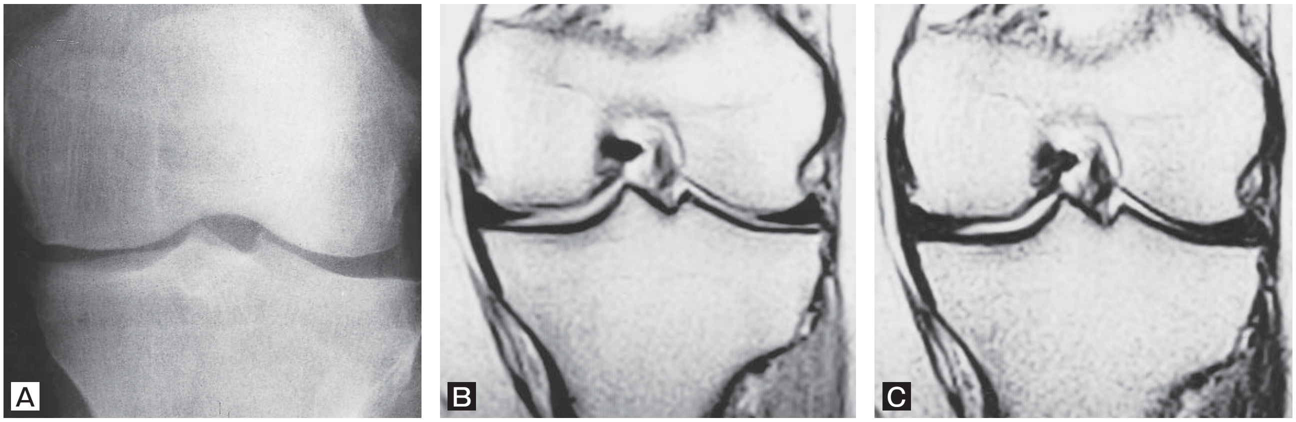

Fig. 1 (A) Prominent spiking of the tubercles of the intercondylar eminence of the tibial plateau in a patient with osteoarthritis of the knee joint. At the corresponding (B) proton density and (C) T2 weighted coronal MRI demonstrated cartilage defects grade 2 at the medial femoral and tibial condyles.

Fig. 2 (A) Moderate spiking of the medial tubercle of the intercondylar eminence of the tibial plateau in a patient with osteoarthritis of the knee joint. In the corresponding (B) proton density and (C) T2 weighted coronal MRI showed no cartilage defect at the medial femoral and tibial condyles. A small lateral meniscal cyst is noted.

Fig. 3 (A) There is no spiking of the tubercles of the intercondylar eminence of the tibial plateau in a patient with osteoarthritis of the knee joint. In the corresponding (B) proton density and (C) T2 weighted coronal MRI, cartilage defects grade 2 at the medial and lateral femoral and tibial condyles are shown.

with cartilage defects (Fig. 3). As such, less spiking of the tibial tubercles is probably not a reliable sign of early OA. Our results show that the presence of tibial spiking as a feature of early OA can not exactly distinguish early OA from established OA in the TFJ. This finding is in agreement with a study by Donelly *et al.* [9] and Boegard *et al.* [1], but not with Reiff *et al.* [14]. The predictive value of spiking of the tibial tubercles for MRI-detected cartilage defects in the TFJ is related to the degree and size of the spiking. Hernborg *et al.* [16] have stated that osteophytes in the TFJ are probably most related to age and are not necessarily an early sign of OA, but osteophytes are frequently observed in cases who develop OA later on, defined as structural changes in the form of subchondral sclerosis and cysts. Our findings support this theory in regard to the presence of tibial spiking or central osteophytes.

We detected primarily slight grade cartilage defects on MRI in the controls. The number of controls was small. However, control subjects did have some special features such as that they were similar in age to patients, and MRI was performed in healthy subjects who were willing to undergo MRI. There were no similar meaningful correlations between spiking and MRI cartilage defects in controls. Previous studies have revealed that the presence or absence of osteophytes is the most reliable radiological marker for OA of the knee in the general population [17].

Reiff *et al.* [14] have demonstrated that lengthening of the medial and lateral tubercles of the intercondylar eminence and sharpening of their angles (also known as spiking) is a feature of established knee OA in TFJ when compared to controls. The reported association was weakest for the height of the medial spike, as in our patients. This weakness might be related to the greater prominence of the medial tubercle and its location anterior to the lateral tubercle. The spiking at the medial tubercles was more prominent than that of lateral tubercles in the patients with OA (Table 1). This greater prominence might have been related to the medial compartment being most frequently affected even in mild OA of the knee [1, 18].

The exact cause of osteophyte formation remains obscure, but there is now good evidence that osteophytes are simply an unvectored development of chondrogenesis occurring in the direction of least resistance [1, 4, 18, 19]. This observation has been made in osteophytes arising at a joint margin, but it seems likely that it could be extended to include osteophytes involving the tibial tubercles. In our study, the association between tibial spiking and marginal osteophytes was significant for spiking of the lateral tibial tubercle, rather than the medial tibial tubercle. In this regard, there might be some resistance differences between the tubercles. The reported association between spiking of the tibial tubercles and osteophytes has been found to be stronger for angulation of the tibial spike, rather than for height, as in our patients (Table 3) [9].

In the present study, spiking in the lateral tibial tubercle was found to be associated with osteophytes at the tibial condyles, especially at the medial condyle. Our findings in the present study give some support to the theory that the presence of medial or lateral meniscus pathology may play a role in this correspondent relation between lateral tibial spiking and tibial marginal osteophytes [1]. Boegard *et al.* [1] have pointed out similar to our results that MRI-detected cartilage defects are more common in the femoral condyles, while the distribution of marginal osteophytes is the reverse, with a stronger presence at the tibial condyle.

In conclusion, our results suggest the following:

1- Spiking of the tibial tubercle may be accepted as a feature of OA in the TFJ. However, the degree and size of the spiking of the tibial tubercles were found to be important in the knee OA. A strong association was found between angulation (if less than 70°) and especially height (if more than 0.16) of the medial tibial spike and MRI-detected cartilage defects in the medial tibiofemoral compartment. The presence of tibial spiking alone may not be a reliable sign of cartilage defects in the TFJ.

2- Spiking of the lateral tibial tubercles was found to be associated with marginal osteophytes in the tibial condyles. This finding gives some support to the theory that tibial spiking is a form of osteophyte formation.

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