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Influence of High Tibial Osteotomy on Bone Marrow Edema in the Knee

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To determine the influence of high tibial osteotomy on subchondral bone marrow edema in medial osteoarthritis of the varus knee, full leg-length radiographs and magnetic resonance imaging were performed in 20 patients (20 knees) before surgery, 1 year postoperatively, and at a mean of 7 years postoperatively. The extent of bone marrow edema in the medial compartment was quantified with magnetic resonance imaging in two planes using the formula for a prolate ellipsoid as follows: length × width × depth × π/6. We used the Japanese Orthopaedic Association knee score for clinical evaluation. At the last followup, all knees with valgus alignment (10/10) showed reduced edema. In contrast, bone marrow edema increased or remained unchanged in four of 10 knees with neutral or varus alignment. The percentage of satisfactory results was 100% (10/10) in valgus knees and only 30% (3/10) in neutral or varus knees. Extent of bone marrow edema at the followup correlated with the mechanical axis and knee score. Because of the prognostic value of bone marrow abnormalities in the medial compartment observed on magnetic resonance imaging, early lateral closing wedge osteotomy should be considered in patients with varus malalignment and bone marrow edema even in mild cases of medial osteoarthritis.

Level of Evidence: Level II, therapeutic study. See the Guidelines for Authors for a complete description of levels of evidence.

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High tibial osteotomy (HTO) is a well-accepted and effective treatment for medial compartment osteoarthritis (OA) of the knee with varus deformity.[4,5,14,17] The rationale for HTO is to correct the mechanical axis, to eliminate the varus thrust with weightbearing, and to shift loadbearing from the osteoarthritic medial compartment to the less affected lateral compartment. Long-term followup studies have shown favorable results especially after moderate surgical over-correction.[5,12,14,17] Recurrence of varus during a period of years has been reported and may lead to poor results.[3,5,10,17,18] High tibial osteotomy is the preferred operative treatment for the relatively young, active patient with medial compartment OA.[17]

Since the advent of musculoskeletal magnetic resonance imaging (MRI), a pattern of bone marrow edema (BME) has become recognized as a nonspecific finding characterized by an ill-defined marrow area of low signal intensity on T1-weighted images and of hyperintensity on short tau inversion recovery (STIR) images and on T2-weighted, fat suppressed MRI.[19,20] If the BME pattern is seen on MRI, several diagnoses must be considered including trauma, stress fractures, osteonecrosis, transient BME syndrome, tumor, osteomyelitis, and reactive changes underlying degenerative articular disease.[9,19] Subchondral bone marrow abnormalities in knees frequently are seen in patients even at the mild end of the osteoarthritic spectrum, and MRI seems uniquely suited for assessing many abnormalities including OA during early stages of the disease.[8,19,20] Medial bone marrow lesions can be observed mostly in patients with varus deformities, whereas lateral lesions can be seen mostly in patients with valgus malalignment, suggesting the influence of overloading to the subchondral bone.[7] In this subgroup of patients, it could be speculated that increased stress created by an angular deformity produces microtrauma with subsequent BME. We assumed BME is associated with mechanical overloading and predicts progression or severity of impending OA. There are no causal treatment options for BME. The biomechanical goal of an HTO is to unload the involved medial compartment by correcting the malalignment. Despite this recognition and concern, HTO as a therapeutic intervention for BME in the medial compartment of the varus knee has not been mentioned in literature, and to our knowledge there are no MRI followup studies of BME after an HTO.

We performed a prospective study to evaluate the influence of an HTO on BME. The specific questions we addressed were: (1) Is the size of the BME decreased, unchanged, or are there any new BME lesions in the medial or lateral tibiofemoral compartment after an HTO?; (2) Has the postoperative extent of edema lesions any relation to the clinical outcome and have the edema lesions any prognostic value?; (3) Is there a correlation between the size of BME and the mechanical axis after an HTO?; and (4) Has the degree of correction into valgus any effect on the BME?

MATERIAL AND METHODS

From February 1996 to October 1998, 59 consecutive patients with medial compartment OA and varus malalignment had lateral closing wedge osteotomies. The senior author (AE) operated on all patients. Each patient had preoperative standard weightbearing radiographs, full leg-length radiographs, and MRI scans. All data were collected prospectively. Thirty-nine of 59 patients had MRI scans that showed signal abnormalities in the medial femoral condyle and/or medial tibial plateau, which were attributed to BME. To be included, the patients with BME in the medial tibiofemoral compartment had to meet the following criteria: (1) clinical involvement (pain) of the medial tibiofemoral compartment; (2) mild radiographic OA of the medial compartment (medial tibiofemoral joint space ≥ 2 mm on a weightbearing extended anteroposterior [AP] view); (3) mild varus malalignment (≥ 2° and ≤ 10° varus mechanical axis determined from standard long-leg radiographs); and (4) all MRI scans had to be performed at our Department of Radiology to measure the size of the edema lesion digitally with high accuracy. Patients with only MRI hard copies performed at outside institutions were excluded because the resolution for accurate measurements was too low and not comparable with the digital measurements. Twenty-six patients met our inclusion criteria.

The followups included standard weightbearing radiographs, full leg-length radiographs, MRI scans, and clinical examinations 1 year after HTO and 6 or more years after osteotomy. Four patients were lost to followup, and one patient had total knee arthroplasty (TKA) 2 years after the HTO. One patient had a nonunion treated by bilateral fixation with plates rendering postoperative MRI impossible. These six patients were excluded. Twenty patients (eight men and 12 women) were evaluated 1 and 7 years after HTO (range, 6–8 years). The average age of the patients at the time of surgery was 57 years (range, 41–69 years). Each patient presented with marrow edema in the medial tibiofemoral compartment. The medial femoral condyle was solely affected in six knees, whereas two knees had edema exclusively in the medial part of the tibial plateau. Simultaneous involvement of the medial femoral condyle and the medial tibial plateau occurred in 12 knees (12 patients) (Table 1).

Closing wedge osteotomy dividing the tibiofibular syndesmosis was performed through an anterolateral approach, accord-

TABLE 1. Preoperative Data

Patient Number	Age at Surgery (years)	Affected FC/Tibial Plateau	Size of Lesion (femoral condyle) (cm^3)	Size of Lesion (tibia) (cm^3)	Mechanical Axis (degrees)	JOA Knee Score
1	61	Medial FC	1.58	0	3	55
2	68	Medial FC + TP	0.3	0.5	4	50
3	69	Medial FC + TP	3.08	1.8	3	50
4	60	Medial FC	0.99	0	7	70
5	59	Medial tibia	0	0.5	5	60
6	45	Medial tibia	0	2.8	3	60
7	57	Medial FC	2	0	5	63
8	67	Medial FC	1.69	0	4	60
9	54	Medial FC + TP	4.25	9	9	65
10	55	Medial FC + TP	5.4	2.88	9	70
11	54	Medial FC + TP	13.95	1.18	6	65
12	62	Medial FC + TP	0.004	1.88	4	65
13	64	Medial FC + TP	0.08	6.72	3	60
14	54	Medial FC + TP	18.38	0.7	7	55
15	34	Medial FC	10.92	0	7	75
16	46	Medial FC	0.61	0	8	59
17	61	Medial FC + TP	1.87	2.03	7	60
18	69	Medial FC + TP	3.38	3.38	6	60
19	48	Medial FC + TP	4.08	1.69	6	70
20	56	Medial FC + TP	3.08	0.35	5	55

FC = femoral condyle; TP = tibial plateau; JOA = Japanese Orthopaedic Association ing to the method reported by Coventry.[5] Fixation was achieved with a Kremser staple and a cortical bone screw (Vitallium, Howmedica, Rutherford, NJ). To determine the desired angle of correction from standard long-leg radiographs we measured alignment as the angle formed by the intersection of the mechanical axis of the femur (the line from the femoral head center to the intercondylar notch center) and the tibia (the line from the ankle talus center to the center of the tibial spine). A knee was defined as varus if alignment was > 0° in the varus direction, valgus if it was > 0° in valgus direction, and neutral if alignment was 0°. The varus deformity generally was overcorrected 2° to 4° to produce a valgus femorotibial angle of 170° to 172°. All standard long-leg radiographs were viewed by two (GO, PB) individuals who were blinded to the results.

The Japanese Orthopaedic Association (JOA) knee score, which allots a maximum of 100 points to a normal knee, was used preoperatively and at followups to assess the clinical outcome. The clinical examinations were evaluated by two observers (AHK, CEB), and the operating surgeon was not involved in the assessment of the clinical outcome. The JOA knee score reflects pain on walking (0–30 points), pain on ascending or descending stairs (0–25 points), range of motion (ROM) (0–35 points), and swelling (0–10 points). The results were classified as excellent if the scores were 91 to 100 points, good if scores were 81 to 90 points, fair if scores were 71 to 80 points, and poor if scores were less than 71 points. Excellent and good results were referred to as satisfactory and fair and poor results were referred to as unsatisfactory.

The MRI examinations were performed on a 1.0-T superconducting system (Magnetom Expert, Siemens, Erlangen, Germany) using a circular polarized flexible surface coil that was wrapped around the knee. A positioning device for the ankle and knee was used to ensure uniformity between patients. Coronal, sagittal, and axial images were obtained for each participant. The field of view was 160 mm and an acquisition matrix of 256 × 252 was obtained for all sequences. Sagittally, T1-weighted turbo spin echo (TSE) (1200/12/3 [repetition time ms/effective echo time ms/section thickness]), T2-weighted TSE (5244/128/4) and gradient echo (DESS 3D 26.8/9/1.4) sequences were performed. Proton density and T2-weighted TSE sequences (2700/15-105/4) were done in the coronal plane, followed by a coronal STIR sequence (3975/30/4) for depiction of marrow edema. Metal artifacts from vitallium osteosynthesis material had minimal influence on the evaluation of marrow signals because lesions were present predominantly in the medial tibiofemoral compartment.

To determine the greatest extension of BME in the medial femoral condyle and tibial plateau, the lateral (length) and cranial (width) extents were measured on the coronal images and the sagittal extent (depth) was deduced in the sagittal plane (Fig 1). All data were digitally computed. The volumes were calculated using the formula for a prolate ellipsoid: length × width × depth × π/6. These measurements were calculated and finally compared preoperatively and at the first and the second followups. For quantification of the lesion size in the medial compartment, the femoral and tibial edema was summed. All MRI scans were viewed by two (GO, PB) individuals who were blinded to the results.

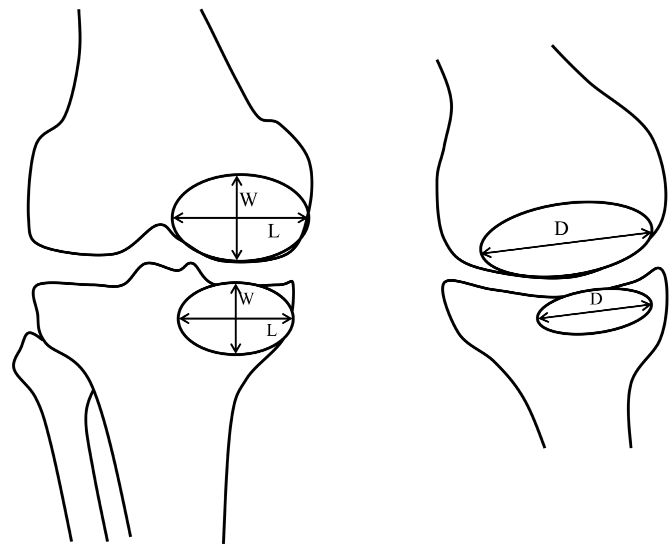

Fig 1. A schematic illustration shows coronal and sagittal MRI sequences with BME in the medial femoral condyle and medial tibial plateau. The greatest lateral (L = length) and cranial (W = width) extents were measured on coronal images and the greatest sagittal extent (D = depth) was measured on sagittal images. The volumes were calculated using the formula for a prolate ellipsoid: length × width × depth × π/6.

To test whether the degree of correction into valgus has any effect on bone marrow lesions, we divided the patients into three groups according to the alignment 1 year after HTO. Group 1 included six patients (Patients 7, 8, 11, 14, 16, and 19) who had a mechanical axis of 3° to 6° valgus, Group 2 had six patients (Patients 1, 3, 4, 5, 10, and 15) with an axis of 1° to 2° valgus, and Group 3 included seven patients (Patients 2, 6, 9, 12, 13, 18, and 20) with neutral or varus alignment of the knee (Table 2).

For statistical analysis all data were expressed as mean and standard deviation. We used a paired t test to evaluate the differences between preoperative and postoperative data. Logistic regression analyses were performed to test the relation between the size of BME to the mechanical axis and the JAO scores at the first and second followups. Categorical variables were compared using chi square analyses. Statistical comparison between the groups was done using Fisher's least significant difference (LSD) test and analysis of variance (ANOVA). Data were considered significant at $p < 0.05$. For interobserver agreement reading alignment and BME size, the Cronbach's alpha coefficient (α) was calculated.

RESULTS

Postoperative MRI findings showed that HTO is effective in reducing the extent of BME in the medial tibiofemoral compartment. The mean size of the BME in the medial femoral condyle decreased ($p < 0.05$) from 4.21 ± 5.11 cm^3 ($\alpha = 0.98$) preoperatively to 1.2 ± 1.32 cm^3 ($\alpha =$

TABLE 2. Postoperative Data

Patient Number	Size of Lesion (FC)* (cm^3)	Size of Lesion (FC)† (cm^3)	Size of Lesion (TC)* (cm^3)	Size of Lesion (TC)† (cm^3)	Axis*	Axis†	Clinical Results*	Clinical Results†
1	0.38	0.41	0	0	−2	0	Excellent	Good
2	2.43	0.1	0.5	0.06	2	6	Fair	Fair
3	2.84	0	0.38	0	−2	−1	Fair	Excellent
4	0.17	0.11	0	0	−2	0	Excellent	Excellent
5	0	0	0.06	0.06	−2	0	Fair	Poor
6	0	0	2.8	2.9	2	6	Fair	Poor
7	0.28	0	0	0	−4	−3	Excellent	Excellent
8	0.1	0	0	0	−6	−6	Good	Excellent
9	1.14	7.5	3.18	3.4	0	3	Good	Poor
10	1.71	0.75	3.42	0.25	−2	−1	Good	Good
11	0	0	0	0	−4	−2	Excellent	Excellent
12	0.004	0.001	1.15	0.78	0	1	Excellent	Excellent
13	1.8	0.32	0.9	0.75	0	3	Fair	Fair
14	1.64	0.35	1.05	0.35	−3	−2	Good	Good
15	0.55	0.48	0	0.06	−2	−1	Excellent	Excellent
16	0.2	0	0	0	−4	−4	Excellent	Good
17	1.87	0.13	2.03	0.4	−2	−1	Excellent	Excellent
18	1.5	6.24	1.5	4.13	2	3	Good	Poor
19	0.04	0	0	0	−4	−3	Excellent	Excellent
20	5	5.94	0.72	0.73	3	5	Poor	Poor

*1 year after high tibial osteotomy †at a mean of 7 years after high tibial osteotomy; FC = femoral condyle; TC = tibial condyle

0.99) at the first followup and remained unchanged at 1.24 ± 2.73 cm^3 ($\alpha = 0.99$) at the last followup (Table 2). The mean lesion size of the medial tibial plateau decreased from 2.52 ± 2.49 cm^3 ($\alpha = 0.99$) preoperatively to 1.26 ± 1.17 cm^3 ($\alpha = 0.96$) 1 year after HTO ($p < 0.05$) and decreased further to 0.93 ± 1.14 cm^3 ($\alpha = 0.99$) at the final followup. Fifteen knees (75%) showed reduction of BME in the medial tibiofemoral compartment and one knee (Patient 11) had complete resolution 1 year postoperatively (Fig 2). In two knees (Patients 2 and 20), size and intensity of preexisting marrow edema increased, and in two knees (Patients 6 and 17), the preexisting lesion in the

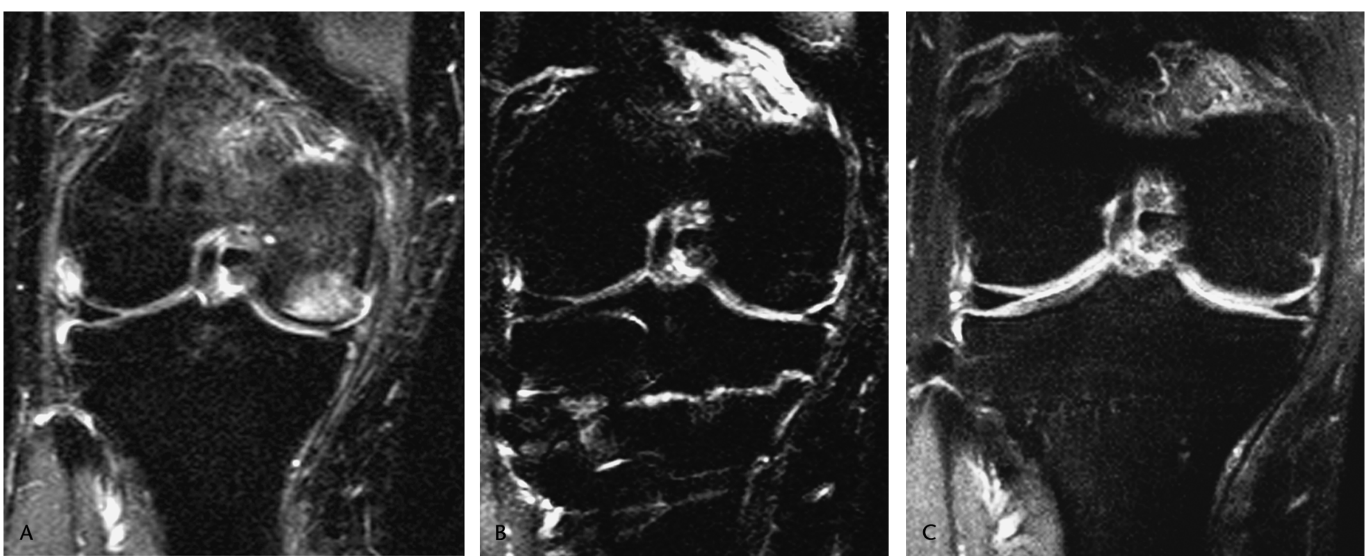

Fig 2A–C. (A) A preoperative coronal short tau inversion recovery (STIR) image of a 57-year-old man (Patient 7) shows subchondral BME in the medial femoral condyle. (B) There was a substantial reduction in size 1 year after HTO. (C) Seventy-nine months after the osteotomy there was complete resolution of the BME in the medial femoral condyle.

medial compartment remained unchanged. At the final followup, eight knees had additional reduction of the BME (40%), and in six knees (30%), the edema disappeared completely (Figs 2, 3). In one patient (Patient 5), the edema remained unchanged, and five knees (25%) showed an extension of marrow edema. These five knees had neutral or varus alignment of the lower limb at the last followup. One patient (Patient 15) had a new small edema lesion (0.06 cm^3) develop in the medial tibial plateau. Magnetic resonance imaging showed no new signal abnormalities in the lateral tibiofemoral compartment at both followups.

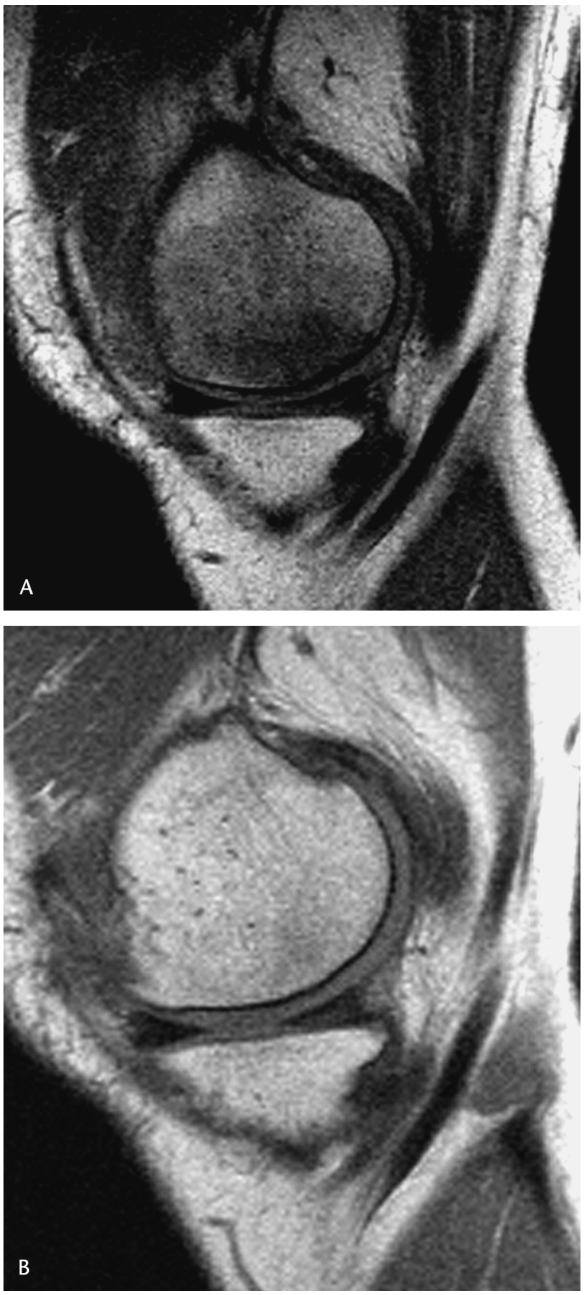

Fig 3A–B. (A) A preoperative sagittal T1-weighted MR image shows the sagittal extent of a subchondral low signal intensity zone as a criterion for BME. (B) There was complete resolution of the edema at final followup.

There was an inverse ($p < 0.01$) correlation between the size of the marrow edema in the medial femoral condyle and the JOA sore at both followups. There was a similar strong inverse ($p < 0.01$) correlation between the lesion size in the medial tibial plateau and the JOA score at the final followup. One year after HTO, 11 knees (11/20) had an edema greater than 1 cm^3 in the medial tibiofemoral compartment. The percentage of satisfactory results was 55% (six of 11 knees) in contrast to 89% (eight of nine knees) in knees with an edema less than 1 cm^3. At the latest followup, six knees (six of 11) with a large edema had substantial reduction of BME (< 1 cm^3), with satisfactory results in five knees. The five patients (five of 11 knees) with unaltered edema greater than 1 cm^3 had unsatisfactory results (100%). In contrast, 87% (13/15 knees) of knees with edema less than 1 cm^3 had satisfactory results. Overall, the mean total JOA score improved ($p < 0.01$) from 61 ± 7 points preoperatively to 89 ± 9 points at the first followup, but decreased slightly to 85 ± 17 at the last followup.

The size of BME in the femoral condyle correlated well with the mechanical axis at the first ($p < 0.01$) and the second ($p < 0.05$) followups. There also was a correlation ($p < 0.05$) between the lesion size of the tibial plateau and the mechanical axis 7 years after the HTO. The average angle of the lower limb was 5.6° ± 2° varus ($\alpha = 0.95$) preoperatively, 1.5° ± 2.4° valgus ($\alpha = 0.96$) at the 1-year followup, and 0.2° ± 3.3° varus ($\alpha = 0.98$) at the 7-year followup. Twenty percent of the knees had recurrence of varus 1 year postoperatively, and 35% had recurrence 7 years after HTO. The percentage of satisfactory results was 85% (11/13) in knees with a valgus angle between 1° to 6° and 43% (3/7) in knees with neutral or varus alignment 1 year postoperatively. At the final followup the percentage of satisfactory results was 100% (10/10) in valgus knees and only 30% (three of 10) in neutral or varus knees ($p < 0.01$). There was an inverse ($p < 0.01$) correlation between the loss of correction and the JOA score at both followups.

One year postoperatively there was a clear association between the reduction of BME in the tibiofemoral compartment and the degree of correction into valgus (Fig 4A). The preoperative size of the BME was comparable between the three groups (Group 1 = 7.38 ± 7.83 cm^3; Group 2 = 4.44 ± 3.93 cm^3; and Group 3 = 5.1 ± 4.26 cm^3). One year after HTO, the size of the BME decreased ($p < 0.01$; Group 1 versus Group 3) to 0.55 ± 1.05 cm^3 in Group 1 compared with 1.92 ± 2.11 cm^3 in Group 2 and

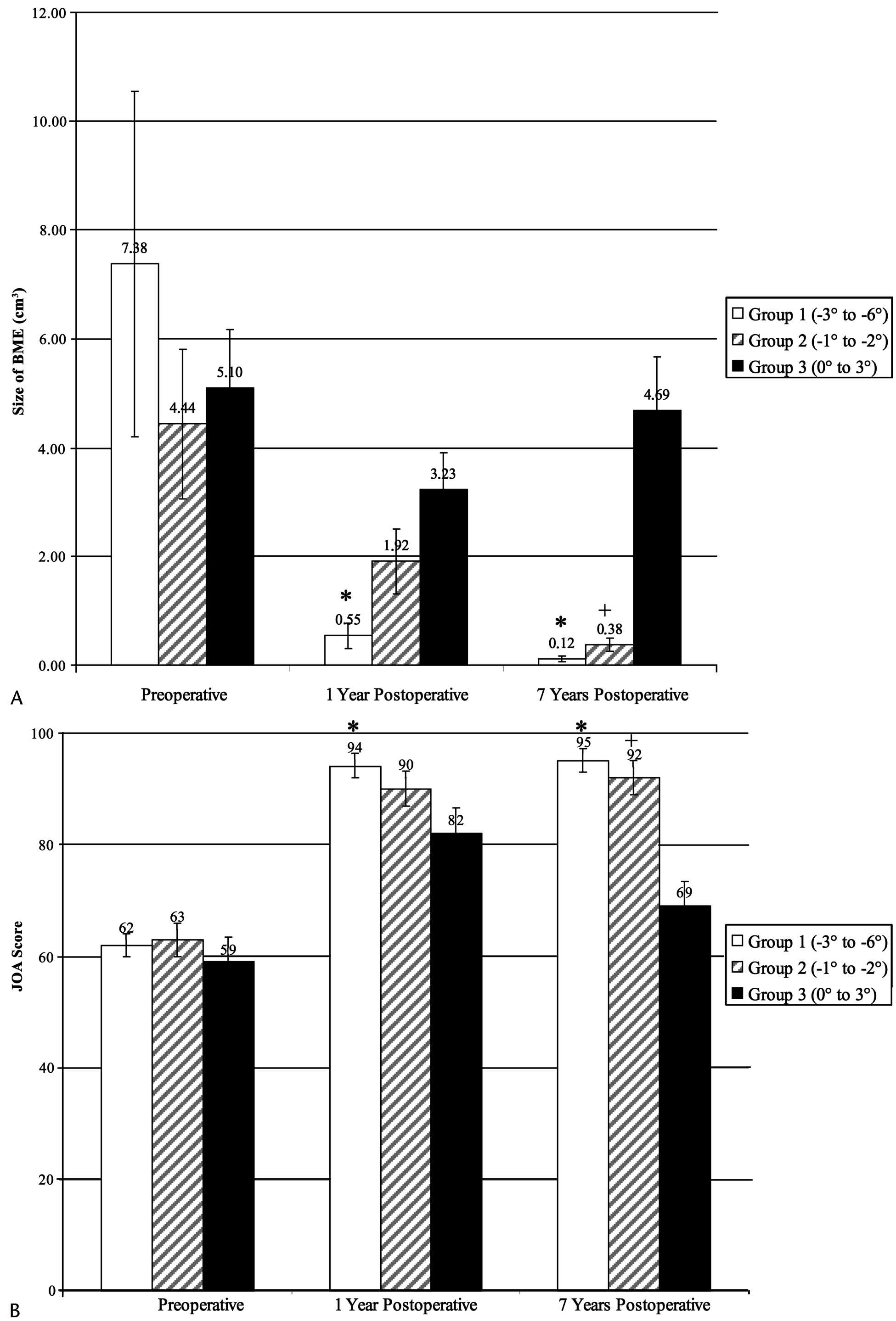

Fig 4A–B. (A) The reductions of BME in the tibiofemoral compartment 1 year and at a mean of 7 years after HTO in three different groups according to the degree of correction are shown. (B) Improvement of the JOA score is shown in the three groups, depending on the degree of correction, after 1 year and at a mean of 7 years after the operation.

3.23 ± 1.43 cm^3 in Group 3. At the last followup, the lesions were 0.12 ± 0.29 cm^3 in Group 1 and 0.38 ± 0.35 cm^3 in Group 2 compared with 4.69 ± 4.57 cm^3 in Group 3 ($p < 0.01$).

The mean JOA score 1 year after HTO was higher ($p < 0.01$; Group 1 versus Group 3) in Group 1 (94 ± 4 points) compared with Group 2 (90 ± 9 points) and Group 3 (82 ± 10 points) (Fig 4B). At the final followup, the knee score was higher ($p < 0.01$) in Group 1 (95 ± 2 points) and Group 2 (92 ± 11 points) compared with Group 3 (69 ± 17 points).

DISCUSSION

Our primary research question was whether HTO would alter the extent of BME in the medial tibiofemoral compartment by shifting load-bearing from the affected medial to the lateral compartment. Our results showed the lesions were reduced after corrective lateral closing wedge osteotomy. The reduction of the marrow edema correlated well with the clinical improvement and correction of the mechanical axis. Our findings support the assumption that BME is associated with mechanical overloading and predicts progression of OA.

There are several limitations to this study. First, to perform accurate digital measurements of the BME size we excluded patients who only had hard copies of preoperative MRI scans. Furthermore, not all patients who volunteered to participate in the study were available at the 7-year followup. Therefore, only 20 patients finally were examined. This limits the power to detect significant relationships. Although the sample size was small, this limitation is compensated for by including only one diagnosis and by ensuring accurate digital measurements of the BME size. The reproducibility of the lesion size was high ($\alpha = 0.96–0.99$). Statistically significant results could be derived from our data.

Another study limitation is that not all enrolled patients had the Knee Society system (KSS) for clinical evaluation. Instead of the KSS, the JOA knee score was used. The JOA score is an established score for evaluating functional results after HTO. We are convinced this had no influence on our findings.

Our results show the size of BME in the medial femoral condyle and tibial plateau decreased after corrective lateral closing wedge osteotomy. The reduction of BME correlated well with the clinical improvement, suggesting BME lesions are strongly associated with the presence of pain in knee OA. Our findings are in agreement with the results of Felson et al.[6] They reported that BME lesions occurred in 50% of persons with pain but in only 4% without pain, and that resolution of pain coincided with the disappearance of marrow edema.[6] Felson et al suggested subchondral BME lesions markedly increase risk for local structural progression in the affected compartment.[7] The risk for medial progression was increased more than sixfold in patients with medial lesions and BME was strongly related to frontal plane malalignment.[7] Pessis et al indicated OA progression is unlikely during the next year in the absence of BME, and emphasized the potential importance of subchondral BME in OA.[13] Our findings are in accordance with these data. The percentage of satisfactory results was 89% in knees with no or a small subchondral edema (< 1 cm^3) 1 year postoperatively and remained unchanged through the last followup. In knees with a large subchondral edema (> 1 cm^3), the percentage of unsatisfactory results was 100% at the last followup, an indicator for progression of OA. Our results suggest persisting large edema lesions predict risk for local structural deterioration.

We also showed a decrease of marrow edema correlated with the mechanical axis after HTO. The association between lower extremity malalignment and the development of subchondral femoral or tibial edema has been documented, and altered mechanical load bearing has been suggested to be an etiologic factor for the origin of BME.[7,15] In a knee with unicompartmental arthritis, limb alignment is altered and subsequently more load is distributed to the affected compartment, causing additional degenerative changes and angular deformity. This vicious cycle of progressive angular deformity and loss of articular cartilage may progress with time. One could speculate that in a knee already affected by chondral damage and meniscal disease, any additional loss of absorbing capacity, either from additional cartilage or meniscal degeneration, could increase peak stresses reaching the threshold for failure of the subchondral plate, leading to microfractures and vascular insufficiency of the underlying bone.[2] This overloading theory presupposes repeated microtraumata causing an accumulation of subchondral stress fractures with subsequent BME creating increased intraosseous pressure and pain.[15] Arnoldi et al reported that patients with knee and hip OA often have poor venous drainage from the marrow with subsequent intraosseous hypertension.[1] This increased pressure in a closed compartment interferes with the blood circulation with resultant osseous ischemia. This hypothesis is in agreement with an histopathologic examination in osteoarthritic knees with BME.[20] Zanetti et al reported that BME lesions reveal surprisingly little edema, but show abnormal bone trabeculae with excessive fibrosis, small areas of osteonecrosis, and extensive bony remodeling.[20] Such remodeling often occurs after microfractures, which would help to explain the association between malalignment with increased stress to the affected compartment and subchondral bone marrow lesions. By treatment with HTO, these loading forces are reduced in the affected medial compartment with subsequent reduction of subchondral BME. At 1 year postoperatively, 12 of the 13 overcorrected valgus knees showed decreased marrow edema, and 11 of 13 knees had clinical improvement with relief of pain. In contrast, three of four patients with subsequent varus alignment revealed an increase of subchondral signal abnormalities and persistence of pain with practically unaltered clinical conditions. Seven years after the osteotomy all 10 valgus knees had reduction or complete resolution of BME and the percentage of satisfactory results was 100%. In neutral or varus knees the percentage of satisfactory results was only 30% (three of 10). This supports our contention that concomitant BME is induced by loading stress and that bone marrow lesions seen on MRI scans are strongly associated with the presence of pain in osteoarthritic knees.

Another important finding was that the degree of overcorrection correlated with the decrease of BME in the medial tibiofemoral compartment (Fig 4A). At the final followup, both groups with slight or moderate overcorrection (Groups 1 and 2) showed a reduction compared with Group 3 with neutral or varus alignment. The clinical results are in accordance with these findings (Fig 4B). We think a statistically significant difference between the two valgus groups (slight and moderate overcorrect), was not present because of the small sample size. However, more surgical valgus corrections resulted in faster reduction of BME and better clinical outcomes. The results confirm the assumption that BME is a finding associated with mechanical overloading and emphasize the importance of sufficient over-correction into valgus angulation.

Subchondral BME is seen frequently on MRI scans of patients with articular cartilage degeneration of the knee. Higher grades of articular cartilage defects are associated with higher prevalence of BME lesions.[11] Kijowski et al observed subchondral BME lesions in 79 (60%) of 132 patients with degeneration of the articular cartilage of the knee.[11] Sowers et al identified BME lesions in 73% of all evaluated painful osteoarthritic knees. Bone marrow edema lesions 1 cm or greater were more frequent (49%) in patients with painful OA compared with patients with painless OA (20%).[16] Felson et al found a strong association between BME lesions and mechanical alignment in 223 patients.[7] Limbs with varus alignment had a remarkable high prevalence of medial lesions (74.3%) compared with limbs that were neutral or valgus (16.4%). These results are in accordance with our data. Thirty-nine of 59 patients (66%) with varus malalignment had bone marrow lesions in the medial tibiofemoral compartment on MRI, and the prevalence of large lesions (> 1 cm^3) was 80%. The remaining 20 patients (34%) had no edema lesion seen in the medial compartment before surgery. These patients, who were not included in the study, obtained comparable clinical results. Therefore, we do not think that the presence of BME is critical to the success of an HTO. However, if BME is observed in the medial compartment, an HTO could be considered to annul the effect of the compartment.

Our study highlights that moderate over-correction leads to reduction of BME, better clinical outcome, and better long-term outcome with less progression of OA. The symptomatic and functional improvements seen after adequate correction of the varus knee suggests an early HTO should be considered in patients with BME in the medial compartment and varus malalignment.

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