Concise report

Dynamic ultrasound assessment of medial meniscal subluxation in knee osteoarthritis

Carlos Acebes¹, Fredeswinda I. Romero¹, Maria A. Contreras¹, Ignacio Mahillo² and Gabriel Herrero-Beaumont¹

Abstract

Objective. Although clinical reports have described medial meniscal subluxation (MMS) in knee OA, few controlled studies have used dynamic US to examine the potential impact of MMS on OA. The aim of this study was to assess MMS in patients with knee OA and in asymptomatic controls by US in different weight-bearing positions.

Methods. In a cross-sectional controlled study, MMS was evaluated by US in 33 symptomatic OA knees and in 13 control knees in supine neutral and unipodal weight-bearing positions. The reproducibility of US in this setting was assessed and the US measurements were compared between patients and controls.

Results. MMS was observed more frequently in OA knees than in controls in the unipodal weight-bearing position both before ($P = 0.014$) and after ($P = 0.035$) walking 50 m. In both OA and control knees, an increase in MMS was observed in the unipodal weight-bearing positions compared with the supine neutral position, but this increase was greater in OA knees than in controls ($P < 0.001$).

Conclusion. Our findings confirm clinical observations that the medial meniscus undergoes significant subluxation in knee OA. The degree of subluxation is greater in weight-bearing than in non-weight-bearing positions. Dynamic US is a reproducible method for the assessment of MMS.

Key words: knee osteoarthritis, dynamic ultrasound, meniscal subluxation.

Introduction

The dysfunction of the medial meniscus is recognized as an aggravating factor in knee OA affecting the medial compartment [1]. Although total meniscectomy has been shown to predispose to premature knee OA [2–4], it remains to be elucidated how other factors, including medial meniscal subluxation (MMS), may impact the evolution and clinical presentation of the disease. The degree of MMS, assessed either by US or MRI, has been shown to correlate with radiographic medial tibiofemoral joint space narrowing in knee OA [5, 6]. In addition, a recently published longitudinal study using US showed that MMS increased significantly over a 1-year follow-up of OA knees [7].

Local pain in the medial tibiofemoral joint is a common symptom in knee OA. The specific origin of the pain is unclear, but studies correlating the intensity of pain with US and MRI findings have found that local soft tissues, such as the menisci and the medial collateral ligament (MCL), are involved [5, 8]. US is an accurate imaging technique for the evaluation of musculoskeletal soft tissues. In the knee joint, US has been shown to be more sensitive than clinical examination for the diagnosis of intra- or periarticular conditions, including effusion, bursitis and meniscal and MCL lesions [9–11]. In contrast to MRI, US makes it possible to conduct repeated and dynamic examinations under different weight-bearing conditions [7, 12] and thus to assess changes related to load and movement.

Although several studies have used US to identify MMS and MCL bulging in connection with medial compartment knee OA [5, 12, 13], only one previous study has assessed MMS by US under different loading conditions in patients and controls [7]. In order to shed light on the feasibility and
reproducibility of US assessment of MMS and on the relationship between MMS and knee OA, we examined changes in MMS under different loading conditions in patients with knee OA and asymptomatic controls.

Patients and methods

Patients and controls

In this cross-sectional controlled study, consecutive patients diagnosed with primary unilateral or bilateral knee OA [14] and attending the outpatient rheumatology clinic were included. Asymptomatic volunteers were recruited as controls. The study was approved by the ethics committee of the Fundación Jimenez Díaz, Autonoma University of Madrid, and signed informed consent was obtained from patients and controls.

Patients were excluded from the study if they were unable to stand during the US examination or had significant alteration of knee alignment, general joint laxity or inflammatory arthropathies, infectious or crystal-induced arthropathies affecting the knee. Other exclusion criteria included prior knee surgery and advanced hip, ankle or foot OA. Due to ethical considerations, controls did not undergo a radiographic examination of the knee, but they were excluded from the study if they had any pre-existing knee symptoms, local surgery or meniscal or ligament injuries identified on clinical examination.

US assessment of the medial compartment structures of the knee

Patients and controls underwent a systematic US assessment of unilateral or bilateral knee using a Logiq 9 ultrasound system (General Electric Medical Systems, Japan) with an 8- to 12-MHz linear transducer. Lengths and areas were measured by the software screen callipers. The images obtained were anonymized, identified and recorded electronically. The medial knee joint was assessed with the patient supine and the knee in full extension and the transducer aligned with the long axis of the limb at the level at which the MCL was most clearly visualized. The skin was marked to ensure the exact placement of the transducer in every US examination. Two more measurements were taken in one-legged stance before and after walking a distance of 50 m. The method used for taking the measurements is described in Fig. 1. The landmarks for the image acquisition were the medial femoral condyle, the medial tibial plateau and MCL. The US image of the MCL is a three-layer structure: two hyperechoic bands separated by a thin hypoechoic zone. The deeper layer closely adheres to the peripheral edge of the meniscal body, but in OA, where the meniscus is frequently extruded and macerated and the MCL is displaced radially, there is insufficient contrast between the two structures in US. However, the intermediate layer, visualized as a hypoechoic band, is always easily identified and was used as the reference landmark.

Assessment of reproducibility

The reproducibility of US measurements of meniscal subluxation distance (BD) and meniscal subluxation area (Ar) was evaluated by calculating intraclass correlation coefficients (ICCs) for measurements in supine neutral, static unipodal weight-bearing and unipodal weight-bearing after walking positions. The measurements were acquired by two experienced rheumatologists (C.A., F.R.), and inter- and intraobserver ICCs were calculated by the two measurements of the more experienced examiner (C.A.) in a blinded evaluation of the US images recorded.

Statistical analyses

MMS was assessed by US measurements of BD and Ar in different positions in patients and controls. The mean BD and Ar of patients and controls were compared by analysis of covariance models, adjusting for differences in the two groups. Ratios between BD and Ar measurements in different positions were evaluated and transformed in order to obtain a parametric distribution. Means and their 95% CIs were calculated, and percentage changes were expressed by taking the inverse transformation over means and confidence limits. Measurements were compared using Student’s t-test for paired data. Ratios were compared between patients and controls by multivariate linear regression models using transformed ratios as dependent variables and adjusting for age. Correlations between MMS and clinical parameters were analysed by Spearman’s rank correlation coefficient. All analyses were performed with SPSS v.11 software (SPSS Inc., Chicago, IL, USA).

Results

Demographic and clinical characteristics

Thirty-three symptomatic knee joints from 25 patients and 13 knee joints from 7 controls were included in the study. Demographic and clinical characteristics of cases and controls are shown in Table 1.

Reproducibility

The ICC for the measurement of BD in the supine and unipodal weight-bearing positions before and after walking was 0.98 (P < 0.0001) and the ICCs for the measurement of Ar in the same three positions were 0.93, 0.90 and 0.96 (P < 0.0001), respectively. The intraobserver ICCs were 0.96, 0.98 and 0.96 (P < 0.0001), respectively, for BD and 0.94, 0.85 and 0.93 (P < 0.0001), respectively, for Ar.

US assessment of MMS

Mean BD was significantly higher in OA knees than in controls, in both the unipodal weight-bearing position (P = 0.014) and the unipodal weight-bearing position after walking (P = 0.035), but not in the supine position (P = 0.802). Mean Ar was significantly higher in OA knees than in controls in all three positions (Table 1).

An increase in the mean BD was observed for both OA and control knees when comparing the unipodal weight-bearing positions with the supine position.
However, this increase in mean BD was greater in OA knees than in controls ($P < 0.001$). No significant difference in mean BD was observed in either cases or controls when comparing the unipodal weight-bearing positions before and after walking (Table 1).

Although an increase in the mean Ar was observed in both OA and control knees when comparing the unipodal weight-bearing position before walking with the supine position, this increase was not significantly greater in cases than in controls. No significant differences in mean Ar were observed either in cases or controls between the supine position and the weight-bearing position after walking or between the weight-bearing positions before and after walking (Table 1).

**MMS and demographic and clinical characteristics**

A correlation between weight and MMS was observed in all positions ($P < 0.05$, $P < 0.01$, $P < 0.05$), and a correlation between weight and Ar was observed in the supine and unipodal weight-bearing positions ($P < 0.05$, $P < 0.01$, respectively). No other correlation between MMS and clinical or demographic characteristics was observed.

**Discussion**

Consistent with previous reports [7, 12], our findings confirm the clinical observation that the medial meniscus undergoes significant subluxation in the OA knee compared with controls. Moreover, the degree of subluxation is significantly higher in the weight-bearing than in the non-weight-bearing supine position.

Since there is no consensus on the best method for assessing MMS by US, we used BD as the MMS distance. BD was defined as the distance from a line running from the femoral and tibial cortices to the internal edge of the intermediate layer of the MCL, easily identified by US as a hypoechoic band. The mean BDs found in the present study are along the lines of MMS distances reported in other studies using US or MRI. Ko et al. [12], using US,

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**Fig. 1** Longitudinal US images of the medial femorotibial joint at the level of the medial collateral ligament (white arrows).
TABLE 1 Clinical and demographic characteristics, US measurements (distance and area) and percentage of change in distance and area for cases and controls

<table>
<thead>
<tr>
<th>Variable</th>
<th>OA (n = 33)</th>
<th>Controls (n = 13)</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)², mean (s.d.)</td>
<td>67.4 (9.3)</td>
<td>54.3 (5.1)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>Weight (kg)², mean (s.d.)</td>
<td>74.0 (13.4)</td>
<td>70.4 (15.1)</td>
<td>0.39</td>
</tr>
<tr>
<td>Height (cm)², mean (s.d.)</td>
<td>158.7 (4.5)</td>
<td>162.0 (7.8)</td>
<td>0.13</td>
</tr>
<tr>
<td>Body mass index, mean (s.d.)</td>
<td>28.4 (5.2)</td>
<td>26.8 (5.4)</td>
<td>0.11</td>
</tr>
<tr>
<td>Sex: female, n (%)¹</td>
<td>30 (90.9)</td>
<td>11 (84.7)</td>
<td>0.64</td>
</tr>
<tr>
<td>BD supine neutral position (mm)², mean (95% CI)</td>
<td>3.96 (3.53, 4.43)</td>
<td>3.35 (3.01, 3.72)</td>
<td>0.802</td>
</tr>
<tr>
<td>BD UWB/P (mm)², mean (95% CI)</td>
<td>5.02 (4.48, 5.62)</td>
<td>3.58 (3.29, 3.89)</td>
<td>0.014*</td>
</tr>
<tr>
<td>BD UWB after walking 50 m (mm)², mean (95% CI)</td>
<td>4.83 (4.32, 5.40)</td>
<td>3.57 (3.29, 3.88)</td>
<td>0.035*</td>
</tr>
<tr>
<td>Ar supine (mm²), mean (95% CI)</td>
<td>0.35 (0.30, 0.40)</td>
<td>0.22 (0.20, 0.25)</td>
<td>0.004*</td>
</tr>
<tr>
<td>Ar UWB/P (mm²), mean (95% CI)</td>
<td>0.38 (0.34, 0.44)</td>
<td>0.23 (0.20, 0.27)</td>
<td>0.0005*</td>
</tr>
<tr>
<td>ΔBD UWB/neutral supine (mm)², mean (95% CI)</td>
<td>1.22 (1.17, 1.29)</td>
<td>1.06 (1.02, 1.11)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>ΔBD UWB after walking 50 m/neutral supine (mm)², mean (95% CI)</td>
<td>1.19 (1.14, 1.25)</td>
<td>1.05 (1.00, 1.11)</td>
<td>&lt;0.0001*</td>
</tr>
<tr>
<td>ΔBD UWB after walking 50 m/UWB/P (mm)², mean (95% CI)</td>
<td>0.96 (0.92, 1.01)</td>
<td>1.01 (0.97, 1.03)</td>
<td>0.3385</td>
</tr>
<tr>
<td>ΔAr UWB/neutral supine (mm²), mean (95% CI)</td>
<td>1.10 (1.02, 1.18)</td>
<td>1.04 (0.94, 1.14)</td>
<td>0.2605</td>
</tr>
<tr>
<td>ΔAr UWB after walking 50 m/neutral supine (mm²), mean (95% CI)</td>
<td>1.03 (0.97, 1.09)</td>
<td>1.07 (0.96, 1.17)</td>
<td>0.5803</td>
</tr>
<tr>
<td>ΔAr UWB after walking 50 m/UWB/P (mm²), mean (95% CI)</td>
<td>0.95 (0.88, 1.01)</td>
<td>1.02 (0.94, 1.11)</td>
<td>0.1585</td>
</tr>
</tbody>
</table>

UWB/P: unipodal weight-bearing position; ΔBD: change in distance; ΔAr: change in area. ¹Student’s t-test for quantitative variables and Fisher’s exact test for qualitative variables. ²Analysis of covariance model adjusted for age. *Results were considered significant if P < 0.05.

identified an MMS distance of 4.8 ± 1.8 mm in weight-bearing conditions, which is similar to the mean BD in our patients (5.02 ± 1.68 mm). Gale et al. [15] used MRI and reported a mean MMS distance of 4.3 ± 3.4 mm in the supine position in female OA knees, which is again similar to our results (3.96 ± 1.2 mm). The mean BD in controls in the present study was 3.35 ± 1.02 mm in the supine position and 3.58 ± 1.36 mm in the weight-bearing position, which is in line with distances reported by Kawaguchi et al. [7] with US (3.52 ± 1.33 and 3.89 ± 1.23 mm, respectively). We have examined the validity of using the MMS area as a method of determining meniscal extrusion. Verdonk et al. [16] used a method similar to ours to evaluate lateral meniscal extrusion in normal and transplanted lateral knee menisci under different axial loading conditions and found that both distance and cross-sectional area measurements were equally good parameters to assess meniscal extrusion.

In the present study, however, although MMS area was able to discriminate between patients and controls, it failed to identify differences in MMS under various loading conditions either in patients or controls. we were observed either in MMS distance or area or under different loading conditions.

In conclusion, despite the limitation of a relatively small sample size in the present study, we have demonstrated that US is a simple and reproducible technique for the assessment of MMS. Furthermore, we have identified an association between MMS and OA knees compared with controls and have shown that the degree of MMS varies under different loading conditions. Bearing in mind that OA prevalence increases with age, our results showing greater MMS in the OA group have to be interpreted with some caution as the control group was significantly younger than the OA group. Apart from weight, no clinical parameters were associated with MMS. Further studies with a larger number of patients are warranted to...
examine other correlations and to set standard methods of measurement and ranges of normality.

**Rheumatology key messages**

- Medial meniscus undergoes significant subluxation in knee OA assessed by US, with a higher degree in the weight-bearing position.
- US is a simple and reproducible technique for the assessment of MMS.

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**References**