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There is no relation between mild malalignment and meniscal extrusion in trauma emergency patients

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ABSTRACT

Objective: To evaluate whether an alteration of the lower limb axis is associated with meniscal extrusion.
Materials and Methods: Ninety-four patients who had complained of knee pain with good knee function and had a knee magnetic resonance image (MRI) and a full-length X-ray taken of the lower limb were included in the study. Meniscal extrusion was measured in the coronal MRI. Subluxation of the meniscus was considered minor or physiological if ⩽3 mm, and major if >3 mm. The extrusion as a percentage of meniscus size was also calculated. Knee alignment (varus, negative value; valgus, positive value) was correlated with the presence of minor and major extrusion.
Results: There were varus knees in 61 cases (58.7%), with a mean measured deviation of −2.63°. Valgus knees were observed in 27 knees (26%) and had a mean deviation of 2.22°. The medial meniscus showed major extrusion in 18 cases (17.3%). It corresponded to 44.7% of the meniscus size. The lateral menisci showed no subluxation in most cases. There was no correlation between alignment and meniscal extrusion in this series, either for the medial meniscus ($p = 0.760$) or for the lateral meniscus ($p = 0.381$).
Conclusions: In patients complaining of knee pain with good knee function, there is no relationship between mild malalignment and the degree of meniscus extrusion.

Introduction

Knee injuries are common following trauma, and such structures as ligaments and menisci can be damaged.[1–3] The meniscus is an integral part of the knee biomechanics. It plays a crucial role in sharing the force load by increasing the contact surface area and providing uniform distribution of weight bearing across the articular surfaces.[4,5] Damage or loss of the meniscus alters this function by modifying the pattern of load distribution, and contributes to compartmental instability.[5] When the meniscus is partially or totally displaced beyond the tibial margin, it is defined as meniscal extrusion.[6] It has been suggested that if the meniscus is extruded beyond the edge of the tibial plateau, leaving the articular surface of the tibia uncovered, it will not fulfill all its functions.[6] In this scenario, the meniscus does not adequately absorb the load applied to the tibial cartilage. This might imitate the effect of a meniscectomy, which alters the physical behaviour of the knee joint.[7] This condition has been found to be associated with joint space narrowing,[8,9] osteophyte formation,[10] the presence of chondral lesions[11,12] and meniscal tears.[12–14] There is no agreement with respect to the amount of meniscal subluxation that can be considered physiological. Several studies used 3 millimeters as a threshold value for meniscal extrusion. Costa et al.[14] considered meniscal extrusion minor when the meniscus is extruded ⩽3 mm and major when the meniscus is extruded >3 mm. Conversely, Choi et al.[12] considered 3 mm as the physiological limit of meniscal subluxation and it is only beyond this limit that the meniscus is considered extruded. Little has been reported about the incidence and predisposing factors relative to meniscal extrusion. Osteoarthritic (OA) knees are known to present a high incidence of meniscal extrusion. However, it has recently been demonstrated that meniscal extrusion is much more common in non-OA knees than had been thought previously.[11] Moreover, a meniscal tear is the only demonstrated predisposing factor to meniscal extrusion in non-arthritic knees.[12,14,15] In fact, there is a high prevalence of meniscal root tears in patients with meniscal extrusion.[16]

Varus or valgus malalignment has also been proposed as a risk factor in knee overload due to an alteration in load distribution across the knee.[17] The mechanical axis of the lower limb is defined as the angle between a line drawn from the centre of the femoral head to the centre of the knee and a line drawn from the center of the ankle joint to the center of the knee. Hip–knee–ankle alignment plays a critical role in load distribution across the articular surface of the knee.[18] Deviation of this axis in varus or valgus is a predisposing

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factor in osteochondral and meniscal tears.[12,19] Thus, it also seems logical to assume that knee malalignment may have something to do with alterations of the anatomical position of the meniscus. To date and to our knowledge, no relationship has been established between malalignment and meniscal extrusion.

The aim of this study was to determine whether an alteration of the lower limb axis is associated with meniscal extrusion. The hypothesis was that axial malalignment in non-OA knees would correlate with meniscal extrusion.

Patients and methods

Patients presenting at our institution with acute traumatic knee injuries were eligible to participate. Inclusion criteria were non-osteoarthritic patients (Kellgren–Lawrence grade 0 or 1) with knee traumatic symptoms who had undergone magnetic resonance imaging (MRI) of the knee as well as full-length radiography of the lower limbs within a maximum time-frame of three months in the period between January 2007 and January 2010 at our institution. They were retrospectively reviewed. Informed consent was obtained from each patient following the guidelines laid down by our local Ethics Committee.

Patients who had fractures, osteochondral injuries or menisci tears on MRI images and/or an arthroscopic revision were excluded.

Overall, 104 knees (53 left, 51 right) corresponding to 94 patients met the inclusion criteria. There were 58 male and 36 female patients with a mean±SD age of 38±11 years. The patients' body mass index averaged 23.2±1.8 kg/m^2.

The patients were distributed into 3 groups according to their main complaint: Group A consisted of the patients with knee instability due to a previous anterior cruciate ligament (ACL) injury; Group B was those patients who had patellofemoral pain syndrome. Finally, group C included patients with non-specific knee pain (Table 1).

Table 1
Main symptoms of 104 knees corresponding to 94 patients

Clinical symptoms	Number of knees
Patello-femoral pain	41 (39.4%)
ACL deficiency	19 (18.3%)
Non-specific pain	44 (42.3%)

Full-length radiograph evaluation

All radiographs were taken in the double-limb standing position. Patients were placed in a true anteroposterior position.[20] Each radiograph was taken so as to include the hip, knee, and ankle joints in one single image. The cylinder was placed perpendicular to the patient at a distance of 20 cm. In order to make the radiographic procedure reproducible, the centres of the femoral head and the ankle joint were determined according to previously defined coordinates.[21] The mechanical axis angle was expressed as a deviation from 180° with a negative value for varus and positive value for valgus alignment.[22]

The radiographic evaluation was performed using a PACS (Picture Archiving and Communication System) workstation (Centricity Enterprise Web V3.0; General Electric Medical Systems. Milwaukee, WI, USA). Each measurement was calculated twice by two of the authors and then averaged. The intra-class correlation coefficients were calculated. Intra-observer reliability was evaluated with a 15-day interval, and was qualified as excellent with a kappa coefficient of 0.96 (95% confidence interval [CI] 0.89–0.98). For inter-observer reproducibility, a kappa coefficient of 0.94 (95% CI 0.88–0.96) was also excellent.

MRI evaluation

MRI of the affected knee was taken in each case. All studies were performed with a 1.5-T superconducting magnet (Signa, General Electric Medical Systems, Milwaukee, WI, USA) using a knee-specific circular coil. A positioning device for the ankle was used to ensure uniformity. The standard knee protocol for each subject consisted of the following sequence: Axial fast-spin-echo T2-weighted with fat saturation (TR: 2300 ms; TE: 30 ms; FA: 90°; ST: 3 mm; FOV: 20 cm), coronal fast spin-echo intermediate-weighted (TR: 2500 ms; TE: 30 ms; FA: 90°; ST: 4 mm; FOV: 18 cm), sagittal spin-echo intermediate-weighted (TR: 700 ms; TE: 14 ms; FA: 90°; ST: 4 mm; FOV: 18 cm) and sagittal fast spin-echo T2-weighted with fat saturation (TR: 2500 ms; TE: 85 ms; FA: 90°; ST: 4 mm; FOV: 18 cm).

MRIs obtained were individually evaluated twice by two of the authors and then averaged. This was also performed using the PACS workstation (Centricity Enterprise Web V3.0). MRI and X-ray evaluations were performed independently. The intra-class correlation coefficients were calculated. Intra-observer reliability was evaluated with a 15-day interval and was qualified as excellent with a kappa coefficient of 0.93 (95% CI 0.831–0.975). For inter-observer reproducibility, a kappa coefficient of 0.91 (95% CI 0.825–0.943) was also excellent.

Meniscal extrusion was measured, using an MRI-generated scale on each image, in those coronal images where extrusion was maximum.[11] Those coronal images usually coincided at the level of the corresponding collateral ligaments.[15] The measurement was performed by drawing 2 lines; first a vertical line that intersected the peripheral margin of the medial/lateral tibial plateau at the point of transition from horizontal to vertical; second, a perpendicular line from the outer margin of the meniscus to the first line. The perpendicular line's length in millimeters was defined as the amount of meniscal extrusion[14] (Fig. 1). According to previous work,[12,14] it

Fig. 1. Magnetic resonance image showing the method used for calculating meniscal extrusion. Distance ab, meniscal extrusion in mm; ab/ac×100, percentage of meniscal extrusion.

was considered *minor* or physiological extrusion when subluxation of the meniscus was ⩽3 mm. Conversely, it was defined as *major* extrusion when the measured subluxation was >3 mm. Afterwards, the extrusion as a percentage of meniscus size was calculated in order to standardise the results. This was performed by dividing each measurement of meniscus extrusion by the total measured width of the meniscus in the same MRI image.

Statistical analysis

A priori sample analysis for the study was calculated based on the assumption that the probability of a valgus patient having different (less or more) meniscus extrusion than a varus patient was 70%.

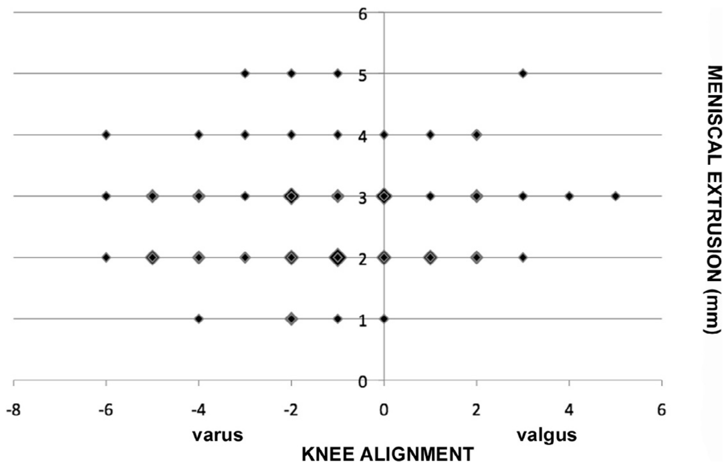

Fig. 2. Scatter plot showing no statistically significant relationship between meniscal extrusion in mm and angle deviation from 180° of the mechanical femorotibial axis (p = 0.76). Each point of the graphic represents a pair of normalised knee alignments and meniscal extrusion. The size of each point correlates with the number of cases. On the horizontal axis, negative values (−) correspond to varus-deviation in degrees. Positive values correspond to valgus-deviation in degrees.

Thus, a sample size of 24 valgus and 48 varus evaluable patients was estimated to have 80% statistical power to detect a difference using the Mann–Whitney U test with a 2-sided significance level of 0.05 (calculated using StudySize 2.0, CreoStat HB).

The relationship between varus alignment and medial meniscal extrusion as well as valgus alignment and lateral meniscal extrusion was analysed with the Kruskal–Wallis test. When any statistically significant difference was observed, the Mann–Whitney U test with Bonferroni correction was used. Meniscal extrusion was also dichotomised into minor (⩽3 mm) and major (>3 mm) and correlated with the kind of alignment (normal, varus or valgus) using the Fisher exact test. For the variables gender and knee-side involved, the presence of any association with meniscal extrusion was calculated with the Mann–Whitney U test. The relationships between the three groups of clinical diagnosis under study and meniscal extrusion was analysed with the Kruskal–Wallis test. Categorical variables are presented as percentages and frequencies. Continuous variables are presented as mean ± standard deviation. Statistical analysis was performed with SPSS version 15.0 for Windows (SPSS Inc., Chicago, IL, USA). The level of statistical significance was set at $p \leqslant 0.05$.

Results

According to the aforementioned measurements alignment was considered varus in 61 knees (58.7%), with an average of −2.63±0.6°. In 27 knees (26%), a valgus alignment with an average of 2.22±0.7° was observed. In the remaining 16 knees (15.4%), alignment was considered normal.

With regard to the medial meniscus, all cases had some degree of meniscal subluxation and 18 cases (17.3%) showed major extrusion (>3 mm). In the cases with major extrusion, extrusion averaged 4.27±0.75 mm, which corresponds to 44.7% of meniscus size (range 27–62%). The remaining 86 knees with minor extrusion (<3 mm) had an average extrusion of 26.4% of meniscus size (range 5–50%). With respect to the lateral meniscus, 27 cases (26%) had some degree of minor meniscal subluxation and none had major extrusion. Subluxation averaged 1.62±0.8 mm, corresponding to a mean of 16.2% of meniscus size (range 8–33%).

The relationship between alignment and meniscal extrusion in this series showed that there was no correlation at all, neither for the medial meniscus (p = 0.76) (Fig. 2) nor for the lateral meniscus (p = 0.38). Moreover, no correlation was observed between either minor or major extrusion and the kind of alignment (normal, varus or valgus) (p = 0.71). Furthermore, no correlation was found between the amount of extrusion and the clinical diagnosis of the medial meniscus (p = 0.73) or lateral meniscus (p = 0.64). Similarly, no such association was observed for the variables gender (p = 0.63 to medial meniscus and p = 0.91 to lateral meniscus) and knee-side involved (medial meniscus, p = 0.17; lateral meniscus, p = 0.52).

Discussion

The results of the present investigation showed that there is no clear relationship between the degree of malalignment and the presence of meniscal extrusion, at least at moderate degrees of axial deviation. This finding contrasted with our hypothesis. Meniscal extrusion has been defined as a situation when the meniscus extends beyond margin of the tibial plateau.[6] It has been shown that this phenomenon is commonly seen after osteochondral lesion and meniscal tears.[12] Most of the extruded menisci present meniscal root tears.[16] In fact, meniscal root tears are uncommon in patients without meniscal extrusion on MRI.[16] Alteration of the ultrastructure of the meniscus after meniscal tears adversely affects the key role that the meniscus plays in the function of the knee. In consequence, the meniscal collagen fibre network, which mainly has a circumferential orientation, will not be able to translate the axial load of the body weight into hoop stresses and will thus decrease contact pressure on the articular surfaces.[23] This was confirmed in a pilot study that we performed in order to test the accuracy and reproducibility of our measuring method. There, the injured menisci showed an average of 1.4 mm more extrusion than a normal meniscus (unpublished data).

There is no agreement with respect to the amount of meniscal subluxation that can be considered physiological. Choi et al.[12] considered 3 mm as the physiological limit of meniscal subluxation and it is only beyond this limit that the meniscus is considered as extruded. Conversely, Miller et al.[10] defined meniscal extrusion to exist when more than 25% of the meniscal body width is beyond the tibial margin. However, the percentage of the meniscus size that was extruded was as high as 50% in medial menisci with meniscal subluxation ⩽3 mm in the present study. In the current work, meniscal extrusion was classified as *minor* when the meniscus was extruded ⩽3 mm and *major* when the meniscus was extruded >3 mm.[14]

Extruded menisci are commonly seen as a cause or effect of joint collapse in the evolution of degenerative knee joint disease (DJD). This might be due to the frequent meniscal tears and cartilage wear observed in these knees. However, the influence of the meniscal degeneration process itself, characterised by the alteration of the collagen network and rupture of the cross-link bridges, may also contribute. Lee et al.[24] have also suggested that, in non-arthritic knees, laxity in the meniscus supporting structures may also be a cause of extrusion. Regardless of the cause, extrusion of the menisci may result in incongruity between the femoral condyle and the tibial plateau and lead to impaired load transmission forces across the knee joint. It has been demonstrated that a clear relationship between extrusion and degenerative knee disease exists.[8] However, no clear relationship between extrusion and other possible contributing factors in non-arthritic knees has been established.

In recent years, the interest in meniscal extrusion has been renewed due to the increasing use of meniscal allograft transplantation. Most of the published series of transplanted menisci showed good knee function but consistently showed some degree of allograft extrusion.[24–29] It has been speculated that this meniscal extrusion could be due to the soft-tissue technique used to fix the allograft.[30] However, no differences in clinical outcomes were seen when analysing the published series performed with different graft fixation methods.[31]

With regard to limb alignment, several attempts have been made to establish the normal alignment values in populations without arthritis. The results indicate that the average for alignment in non-arthritic knees is close to neutral, meaning 180°. Varus or valgus misalignment alters stress distribution in the knee and is considered a predisposing factor for cartilage loss and finally osteoarthritis.[32–35] Cicuttini et al.[36] have recently calculated that for every degree of malalignement, the articular cartilage shows a 17.7 μl loss of its volume. Conversely, cartilage loss has been thought to be one of the major determinants of alignment. The progression of knee OA seems to be determined, in part, by the mechanical effects on local structures. One of the mechanical influences in cartilage loss is limb alignment. Considering that extruded menisci are commonly seen in the evolution of DJD, one can assume that an overloaded compartment can also provoke some degree of meniscal extrusion due to joint collapse. However, to date, this postulate has not been demonstrated in the literature. In addition, the findings observed in the current study do not support this association either.

One of the limitations of this study is that the amount of malalignment was moderate (maximum 6°) and that the biomechanical behaviour of the misaligned knee will worsen as malalignment increases. In addition, as extrusion was studied in images taken in supine decubitus, one might think that the amount of extrusion will increase in the standing position due to a higher load. However, this is a common limitation observed in the studies of this area.[6,8–11,13–16,28] Another limitation, derived from its retrospective nature, is that the sample has been extracted from a clinical database of symptomatic patients. Therefore, we cannot guarantee that the same results would be found in a large series of non-symptomatic patients. However, no relationship between ACL deficiency, patellofemoral pain or nonspecific knee pain with meniscal extrusion has been established.

In conclusion, in patients complaining of knee pain but with good knee function, no relationship was found between mild malalignment and the degree of extrusion.

Disclosure statement

The authors declare that none of them has received anything of value from or owns stock in a commercial company or institution related directly or indirectly to the subject of this article.

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