

# Role of Alignment and Osteotomy in Meniscal Injuries



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## KEYWORDS

• Alignment • Osteotomy • Meniscus • Meniscectomy • Varus • Valgus

## KEY POINTS

- The menisci and lower limb alignment are intrinsically linked in the distribution of forces across the knee joint.
- Lower limb alignment should be assessed in each case of meniscal injury.
- When meniscus tears undergo repair surgery, several factors should be considered to determine whether a concomitant osteotomy is necessary.
- The most relevant factors to take into consideration are concomitant cartilage injuries, whether the meniscal injury is traumatic or degenerative, the meniscal tear pattern, and anterior cruciate ligament status.

## INTRODUCTION

The menisci and lower limb alignment both play a crucial role in load transmission across the knee joint. The meniscus distributes the mechanical load by increasing the contact surface area, sharing the weight bearing across the articular surfaces.<sup>1</sup> Any loss of functional meniscal tissue alters this function and contributes to

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compartmental instability. Similarly, varus or valgus malalignment contributes to knee overload by altering the load distribution across the knee.<sup>2</sup> As meniscal pathology is commonly combined with malalignment, both aspects should be assessed when evaluating meniscal injury. This study reviews and analyzes the most important aspects to be considered in this scenario and highlights indications for isolated and combined treatments.

### **BIOMECHANICS OF THE MENISCI**

The menisci distribute the load across the knee and also stabilize the joint during motion. However, because of the anatomic differences of the medial and lateral compartments, the biomechanical properties of the medial and lateral menisci differ. Although the medial compartments have a concave form, the lateral tibial plateau is smaller and more convex. The corresponding menisci are shaped to conform to these differences. Due to the convex shape of the lateral tibial plateau, this compartment is less congruent and the lateral meniscus transfers a greater load during weight bearing.<sup>3</sup> As a result, any amount of meniscal tissue resection decreases the contact area and increases the peak loads transmitted to the tibial plateau.<sup>4</sup> In a normally aligned knee, the lateral and medial compartments carry 42% and 58%, respectively, of the total load. However, due to its shock absorber property, the menisci transfer only 70% of the total load to the tibial plateau.

### **BIOMECHANICS OF LOWER LIMB ALIGNMENT**

The most relevant aspects of lower limb alignment in relation to the meniscus are those that comprise the coronal plane. Most studies in the literature have assessed alignment in osteoarthritis (OA) and only a few have done so in healthy young individuals. Bellemans and colleagues<sup>5</sup> assessed lower limb alignment in healthy young adults without knee problems. They found a mean hip-knee-ankle (HKA) angle of 1.9° of varus (SD ±2.4) in men and an angle of 0.81° (SD ±2.1) in women. Sixty-six percent of men and 80% of women had an HKA between 3° of varus and 3° of valgus. A varus alignment of more than 3° was observed in approximately 32% of men and 17% of women. Conversely, valgus alignment of more than 3° was only seen in 2% to 3% of cases.

The aim of osteotomy is to shift the load to the nonaffected compartment. The contact pressure in the unloaded compartment depends on the degree of alignment correction and whether a varus or a valgus osteotomy is being performed. In any case, a 7° varus or valgus osteotomy could unload the affected compartment by up to 70%, matching that of the meniscus shock absorber effect.<sup>6,7</sup>

### **DEALING WITH A PROBLEM OF THE MENISCUS OR ALIGNMENT?**

As meniscus function and knee alignment are closely related, they must both be assessed when either of the 2 conditions is diagnosed. For the medial compartment, alignment is of paramount importance. There is an ongoing debate in the literature regarding OA progression and the effect of alignment. Sharma and colleagues<sup>8</sup> found OA progression correlated with alignment, with significantly higher functional deterioration over 18 months when malalignment was greater than 5° either in varus or valgus. Thorlund and colleagues<sup>9</sup> also reported that the load transfer changes after meniscectomy. They found knee load indices increased 12 months after arthroscopic partial meniscectomy (APM), indicating compartment overload. Alignment also has been implicated in OA progression after meniscus resection. Covall and Wasilewski<sup>10</sup> found

less joint space narrowing more than 5 years after medial meniscectomy in patients with a preoperative tibiofemoral valgus of more than  $4^\circ$ . Burks and colleagues<sup>11</sup> found more joint space narrowing 15 years after partial medial meniscectomy for varus with less than  $0^\circ$  in HKA as the cutoff. In contrast, in a regression analysis of 500 patients more than 10 years after APM, Chatain and colleagues<sup>12</sup> did not identify alignment as a significant factor in OA progression.

Varus alignment is also a risk factor for medial meniscus posterior root tear (MMPRT).<sup>13</sup> Hwang and colleagues<sup>13</sup> compared MMPRT with other meniscus injuries and found a mean of  $4.5^\circ$  (SD  $\pm 3.4$ ) of varus in the MMPRT group and  $2.4^\circ$  (SD  $\pm 2.7$ ) of varus in the group with other meniscal injuries.

Meniscal repair can also be influenced by lower limb alignment. Due to the mobility of the menisci and to the role of the menisci in load transmission, it seems logical that varus or valgus alignment might respectively affect the healing potential of a medial or lateral meniscus repair. Surprisingly, no studies have addressed this aspect in detail. Since the adoption of a more comprehensive approach to root repair and meniscus transplantation in recent years, our understanding of the influence of alignment on meniscus injuries has evolved. The etiology of posterior root injury differs between the lateral and medial menisci. The more mobile lateral meniscus posterior root is frequently injured in a traumatic event in a younger person, usually when an anterior cruciate ligament (ACL) injury occurs.<sup>14</sup> In these circumstances, Okoroha and colleagues<sup>15</sup> reported that malalignment might be a risk factor for a lateral meniscus posterior root tear (LMPRT). With a varus angle of more than  $3^\circ$ , they found a 5.2-fold increase of LMPRT. They also observed that a posterior tibial slope of more than  $12^\circ$  was related to a 5.4-fold increase of this LMPRT. These findings highlight the stabilizing effect of the lateral meniscus as a secondary constraint to anterior tibial translation and the internal rotational force in an ACL injury. In contrast, the more tethered medial meniscus posterior root injury is most often part of a degenerative process, with varus malalignment, overweight, OA, and gender being the most common risk factors.<sup>14</sup>

## MEDIAL AND LATERAL MENISCUS IN VARUS AND VALGUS ALIGNED KNEES

Several investigators have reported clinical correlations between alignment and OA.<sup>16,17</sup> However, the deleterious effect on the articular cartilage due to malalignment and meniscus injuries has been little studied, and the influence of alignment on the outcome after meniscectomy is controversial. Although some believe that malalignment compromises the result of meniscectomy,<sup>18</sup> others have stated that the lower limb axis does not affect the outcomes.<sup>12</sup> One of the main reasons for this controversy is that preoperative alignment was not considered in many long-term studies after meniscectomy, and therefore, it was not assessed as an independent risk factor influencing clinical outcomes or osteoarthritis progression.

The effect of meniscectomy on postoperative alignment has been better studied. Findings have revealed an increase in valgus alignment after lateral meniscectomy<sup>19</sup> and also after medial meniscectomy.<sup>20</sup> It seems that the deformity produced by the meniscectomy is influenced by the amount of resected meniscal tissue, but not by the preoperative alignment.<sup>20</sup> The study with the longest follow-up to date, 40 years, analyzed the tibiofemoral angle modification after meniscectomy and showed that a meniscectomy led to malalignment in the corresponding tibiofemoral compartment.<sup>21</sup> However, this effect was more pronounced after a medial meniscectomy leading to a varus knee than after a lateral meniscectomy leading to a valgus knee. The tibiofemoral angle, the magnitude of malalignment, and the range of motion were strongly

correlated with both Ahlback and Kellgren and Laurence scores. Be that as it may, patient-reported outcome measures did not correlate with the degree of OA.<sup>21</sup> In fact, long-term follow-up after arthroscopic partial medial or lateral meniscectomy showed progressive degenerative radiographic changes, with small or no significant negative effects on knee function. One possible explanation is that body mass index (BMI) and degenerative meniscal tears are stronger risk factors for these degenerative changes than the degree of malalignment.<sup>22</sup> It is generally accepted that cartilage deterioration is more frequently observed after lateral meniscectomy than after medial meniscectomy. This higher deleterious effect on the articular cartilage after lateral meniscectomy could be due to the convexity of the lateral tibial plateau being compensated with a larger meniscus covering more area than in the medial compartment.<sup>22</sup> Finite elements analysis supports these concepts, showing that the maximum stresses and strains occurred on the medial tibial cartilage after medial meniscectomy only in a varus knee. Conversely, the drop from before to after in the contact stresses and strains was higher in the lateral cartilage after lateral meniscectomy regardless of whether the lower limb had a valgus or varus alignment.<sup>23</sup>

The increase in peak contact stress after loss of meniscal tissue is directly related to the amount of tissue resection.<sup>4</sup> The volume of removed meniscal tissue should also therefore be considered at the time of the surgery, given that it affects long-term radiological and clinical outcomes both in the medial and lateral compartments<sup>11</sup> (**Box 1**).

Brophy and colleagues<sup>24</sup> studied different factors in patients with reconstructed ACL. They found that varus alignment was associated with articular cartilage status in the medial compartment but not in the lateral compartment. Medial cartilage status was also correlated with BMI, whereas lateral compartment chondral injuries were significantly associated with age.<sup>24</sup> For both compartments, they observed a relevant association with meniscal status. Patients with previous partial meniscectomy showed higher rates of degenerative changes than patients with previous meniscal repair or no previous meniscal surgery.<sup>24</sup> In view of these observations, in an ACL reconstructed knee,

- Varus deformity is an independent risk factor for the development of medial osteoarthritis
- The combination of medial meniscectomy and varus alignment could increase the risk of cartilage degeneration
- Valgus deformity is a risk factor only for lateral OA when it is associated with advanced age or previous meniscectomy. In such patients, the association of medial meniscectomy and varus malalignment could increase the risk of cartilage degeneration.

#### **Box 1**

##### **Known facts between meniscectomy and malalignment**

- Varus and valgus alignment tend to increase after medial and lateral meniscectomy, respectively.
- This increment is more pronounced in the medial compartment.
- The cartilage deterioration is more pronounced in the lateral compartment.
- The deformity after surgery is more related to the amount of resected meniscal tissue rather than to the degree of preoperative alignment.
- The deformity after surgery does not correlate with functional outcomes.

Although a correlation between alignment correction and the healing capacity of a meniscal repair has not yet been clearly demonstrated, some studies have found a high percentage of posteromedial root tears healed following a medial valgus osteotomy.<sup>25</sup>

### INDICATIONS FOR ISOLATED OR COMBINED TREATMENT

Osteotomy is a load-shifting procedure with well-documented favorable outcomes even in subjects with a high activity level. To achieve optimal surgical results, appropriate patient selection is mandatory. First, it is crucial to acknowledge the factors that negatively affect the results of an osteotomy (**Table 1**).

There is no clear consensus or scientific data on which to base a specific cutoff value of alignment to perform a varus or valgus osteotomy around the knee, perhaps because the severity of the symptoms does not always correlate with the degree of deformity. For varus malalignment, for example, it has been demonstrated that patients with a mild degree of preoperative deformity (3° to 5°) have the same baseline characteristic and the same postoperative outcomes as patients with a higher degree of preoperative deformity.<sup>26</sup> In some scenarios, differences as small as 2° between the mechanical axis of the 2 lower limbs could justify an osteotomy. This could be the case if

- Meniscal repair, large meniscal resection, or articular cartilage treatment is to be performed.
- The difference in the chondral status between the affected compartment (International Cartilage Repair Society [ICRS] grade 3–4) and the nonaffected compartment (ICRS 0–1) is clearly evident.

The precise characteristics of the meniscus tear also must be considered when determining the best surgical technique in each case. In cases of malalignment associated with meniscal injuries, it first should be elucidated whether the pain originates in the meniscal injury or in the malalignment. Two crucial parameters to consider are as follows:

- Whether the meniscal lesion is traumatic or degenerative
- The pattern of the meniscal tear.

**Table 1**  
Contraindications and prognostic factors that worsen the results after a knee osteotomy

<b>Avoid Valgus Osteotomy if:</b>	<b>Avoid Varus Osteotomy if<sup>33</sup>:</b>
Severe medial OA <sup>27</sup>	Extreme valgus deformity with tibial subluxation
Patellofemoral OA <sup>28</sup>	Gross knee instability
Lateral OA <sup>28</sup>	Tricompartmental OA
Range of motion deficits <sup>29</sup>	Flexion contracture >15°
Lateral tibial thrust <sup>29</sup>	Severe patellofemoral OA, high BMI, rheumatoid arthritis, age >65 y, and severe lateral compartment bone loss also should be excluded

BMI to determine whether to perform HTO or not is controversial<sup>32</sup>

*Abbreviations:* BMI, body mass index; HTO, high tibial osteotomy; OA, osteoarthritis.

### ***Traumatic or Degenerative Meniscal Tear***

There is now a certain consensus concerning treatment of degenerative meniscus in middle-aged patients, but it is not exempt of controversy.<sup>27,28</sup> Several investigators have suggested that a degenerative meniscal lesion may be an early sign of knee OA rather than a separate clinical problem requiring meniscal intervention.<sup>19</sup> However, it is difficult to discriminate between symptoms caused by a meniscus tear and symptoms of early-stage OA.<sup>27</sup> Certainly, in case of symptomatic *degenerative* meniscal lesions associated with malalignment and cartilage degeneration, an osteotomy at the time of partial meniscectomy is suggested. However, if cartilage degeneration is absent, an isolated meniscectomy is still the gold standard.

- Osteotomy is needed in concomitant cartilage degeneration
- Isolated meniscectomy otherwise

In the case of traumatic meniscal tears with no cartilage changes in a malaligned knee, the treatment of choice is an isolated meniscal procedure. It is of utmost importance in this overloaded compartment to try to perform a meniscal repair rather than a meniscectomy. If symptoms do not improve after a large meniscectomy of a traumatic injury, an osteotomy could then be performed in a second-stage surgery. In this case, a concomitant meniscal transplantation also should be considered in young patients.<sup>29</sup>

When a traumatic meniscal injury is associated with articular chondral injuries in a malaligned knee, the origin of pain can be difficult to identify. In these cases, a combined osteotomy is preferred, especially if the lesion requires a meniscectomy. This viewpoint is based on the fact that symptoms from cartilage injuries can worsen after a meniscectomy and a load-shifting procedure will likely improve both sources of pain.

- Isolated meniscal resection or preferably meniscal repair if there is no deterioration of cartilage
- Osteotomy at index surgery if cartilage injury is present
- Osteotomy in a second stage if symptoms do not subside

### ***Meniscal Tear Pattern***

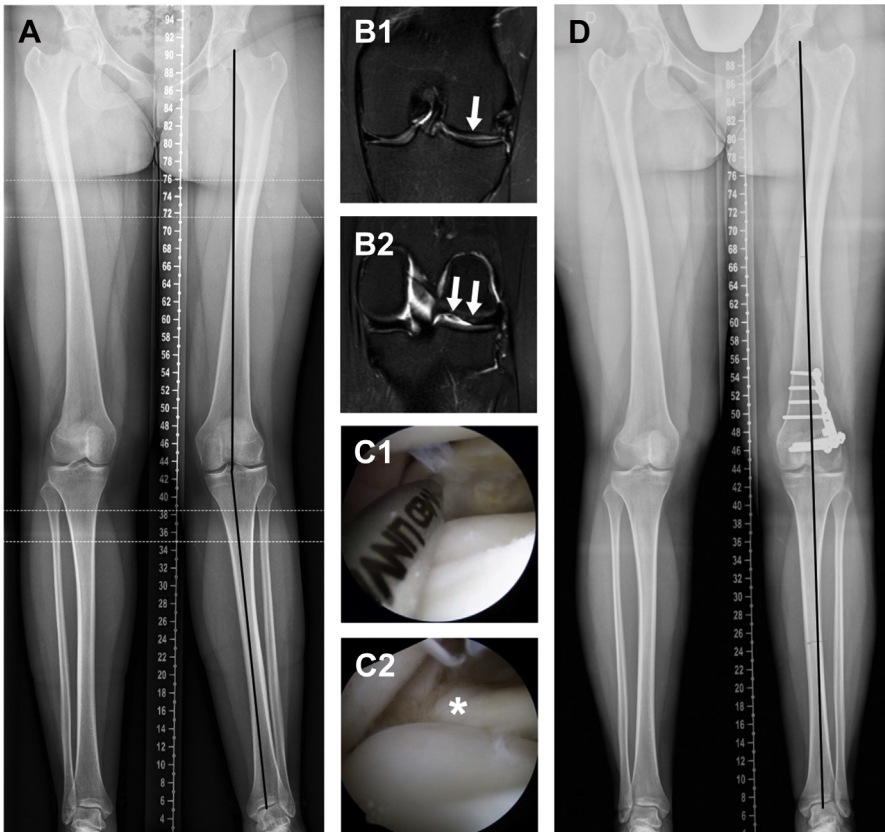
The presence of an MMPRT or complete radial tear of the posterior horn leads to a loss of the hoop stress mechanism, thus predisposing to OA changes.<sup>30</sup> These lesions are frequently accompanied by meniscal extrusion that is also correlated with OA progression.<sup>31</sup> Surprisingly, although meniscal extrusion does not seem to correlate with the degree of mechanical axis malalignment,<sup>32</sup> a recent study showed that it is correlated with the medial proximal tibial angle (MPTA).<sup>33</sup> This suggests that patients with a combination of low MPTA and meniscal extrusion could be appropriate candidates for early intervention with a high tibial osteotomy, supporting the concept of performing an osteotomy when facing a root tear or a complete radial tear with any degree of deformity. This view is also reinforced by the correlation between alignment correction and the previously discussed healing capacity of a meniscal repair.<sup>25</sup>

Perform a concomitant valgus osteotomy in cases of an MMPRT or complete radial tear in the posterior horn of the medial meniscus.

The same can also be applied to the lateral femorotibial compartment in a valgus aligned knee.

Perform a concomitant varus osteotomy in cases of an LMPRT or complete radial tear in the posterior horn of the lateral meniscus (Fig. 1).

It goes without saying that age and chondral status also must be taken into account. In any case, the degree of deformity should not influence the final decision. When a meniscal extrusion is present in combination with a varus or valgus alignment, it must be determined whether or not the extrusion is due to a hoop tension injury of the meniscus. If this is the case, the rationale has already been pointed out. If not, it can be assumed that the meniscal rim is already degenerated and is no longer functioning as a shock absorber. A combination of osteotomy and meniscectomy of the



**Fig. 1.** A 23-year-old woman with no history of previous surgeries presenting with a valgus knee and LMPRT in her left knee. (A) Long standing radiograph showing a mechanical axis of 6° of valgus. (B) Coronal MRIs showed no joint space narrowing or cartilage damage (B1, arrow) and the LMPRT (B2, double arrow). (C) Arthroscopic views where the posterior root of the lateral meniscus is being repaired (C1), and once the root has been reattached (C2, asterisk). (D) Postoperative long standing radiograph after the distal varus osteotomy and repair of the LMPRT showing a corrected mechanical axis of 0°.

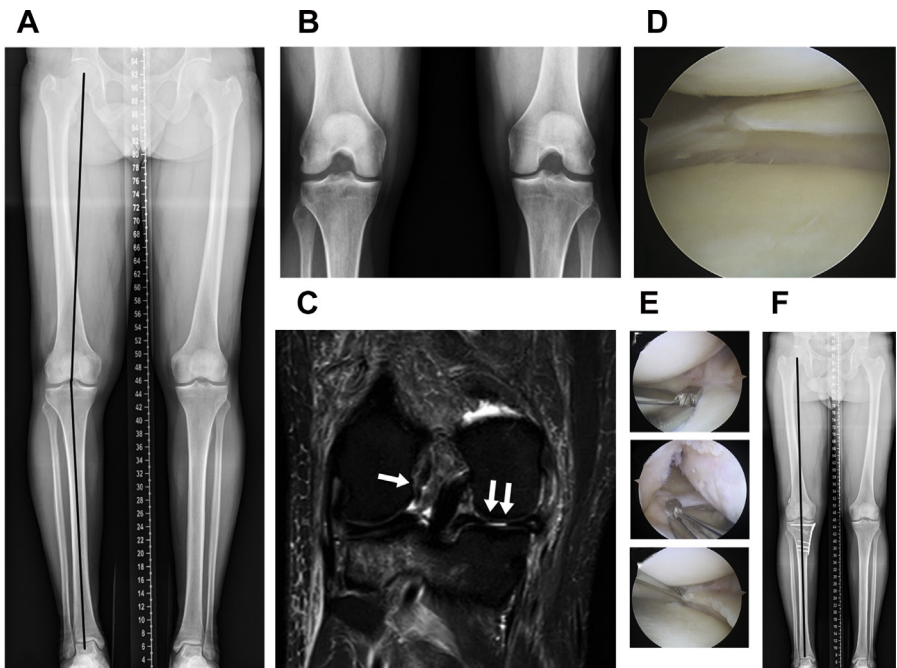
more unstable meniscal flap is then suggested. This is even more important if the deformity is due to a low MPTA, as previously discussed.

### Other Specific Cases

*Discoid lateral meniscus in association with a constitutional valgus alignment.* In patients younger than 20 years, a lateral meniscectomy of a torn discoid lateral meniscus leads to a significantly higher valgus deformity than in large nondiscoid lateral meniscectomy.<sup>34</sup> A prophylactic varus osteotomy should therefore be considered in this subgroup of patients when a wide meniscectomy is necessary.

*Obesity* is likely to have both biomechanical and biochemical links to osteoarthritis, and a recent study demonstrated that it modulates changes in the gene expression of meniscal tears.<sup>35</sup> In cases of malalignment associated with meniscal lesions in the obese, therefore, we should theoretically opt for alignment correction to avoid early OA. On the other hand, it should be kept in mind that obesity is a risk factor for nonunion. Nonunion also should be taken into account in the presence of other risk factors, such as smoking, diabetes, or vasculopathy.

*ACL deficient knees* are suitable for osteotomy if associated with unicompartmental OA, and even without combining ACL reconstruction, osteotomy provides good



**Fig. 2.** A 30-year-old man with mild varus, ACL injury and complete radial tear of the medial meniscus in the right knee. (A) Long standing radiograph showing a mechanical axis of 5° of varus. (B) Weight-bearing posteroanterior radiograph at 30° of knee flexion shows no joint space narrowing. (C) Coronal MRI showing ACL tear (*arrow*) and complete radial tear of the posterior horn of the medial meniscus, with no evident articular cartilage injury (*double arrow*). (D) Arthroscopic view confirming the complete radial tear of the posterior horn of the medial meniscus with a healthy cartilage. (E) Three arthroscopic views of the large meniscal resection performed. (F) Postoperative long standing radiograph after the high tibial valgus osteotomy and ACL reconstruction showing a corrected mechanical axis of 0°.



outcomes.<sup>36</sup> The opposite scenario is more challenging. Considering the increased incidence of medial compartment chondrosis at the time of revision ACL surgery in patients with varus malalignment and deficient medial meniscus, varus knees undergoing large medial meniscal resections at the time of ACL reconstruction have the potential to benefit from a high tibial osteotomy to reduce the risk of medial OA<sup>24</sup> (Fig. 2). As this is a more prophylactic indication, other variables, such as BMI and the patient's daily activities, also should be considered.

## SUMMARY

Meniscus injury together with alterations in lower limb alignment is commonly observed in clinical practice. Several factors must be considered for correct diagnosis and to choose the best treatment option. To obtain a clear, complete picture of each meniscal condition, lower limb alignment should be systematically assessed in all patients. A tailored approach considering the previously detailed, most relevant aspects for each patient is then recommended.

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