



■ REVIEW ARTICLE

The consequences of meniscectomy

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The menisci of the knee have an important role in load-bearing and shock absorption within the joint. They may also function as secondary stabilisers, have a proprioceptive role, and aid the lubrication and nutrition of the articular cartilage. Complete or partial loss of a meniscus can have damaging effects on a knee, leading to serious long-term sequelae.

This paper reviews the consequences of meniscectomy and summarises the body of evidence in the literature regarding those factors most relevant to long-term outcome.

The menisci are two crescentic wedges of fibro-cartilage positioned between the tibia and the femur in the medial and lateral compartments of the knee (Fig. 1). They used to be considered the vestigial remnants of a muscle within the knee, but it is now recognised that they have various important functions. They act as load sharers¹ and shock absorbers,² and are also functioning secondary stabilisers,³ particularly in the absence of a functioning anterior-cruciate ligament (ACL).⁴ Further roles have been postulated in proprioception,⁵ joint lubrication⁶ and nutrition of the articular cartilage.⁷

Meniscal tears are the most common injury of the knee, with an incidence of meniscal injury resulting in meniscectomy of 61 per 100 000 population per year.⁸ They may occur in acute knee injuries in younger patients, or as part of a degenerative process in older individuals. Medial meniscal tears occur more frequently than tears of the lateral meniscus, at a ratio of approximately 2:1.⁹

Acute meniscal tears may be radial, vertical-circumferential or horizontal-cleavage in orientation. The central portion of a circumferential tear may be unstable, and can displace inwards within the relevant compartment of the knee. It is then known as a bucket-handle tear, and frequently causes mechanical locking of the knee. Degenerative tears tend to be complex in morphology and to occur mostly in the posterior horn.

Meniscectomy used to be considered a benign procedure and, as stated by McMurray in 1942,¹⁰ it was felt that “A far too common error is shown in the incomplete removal of the injured meniscus”. This attitude was based on observations suggesting that remnants of meniscus in the joint were a potent cause of arthritis. However, it was actually recognised as far back as 1923 by McNeill Love¹¹ that the prognosis after meniscectomy should be guarded. He observed that “the occasional pain was usually associated with changes in the weather, suggesting its association with secondary osteoarthritis”.

After the publication of King's¹² paper in 1936 describing the function of the semilunar cartilages, awareness of the true importance of the menisci grew,^{13–16} and the consequences of meniscectomy are now widely appreciated.

The mechanical and biochemical effects of meniscectomy

In a study on human cadavers in 1976, Krause et al¹⁷ showed that the menisci perform a load-transmitting and energy-absorbing function in the knee joint, and that stress acting on the joint surfaces increases significantly after meniscectomy. In 1986 Baratz, Fu and Mengato¹⁸ studied the effects of meniscectomy on contact areas and the stresses in the knee joints of human cadavers using pressure-sensitive film. **Loss of the medial meniscus led to a decrease in contact areas of approximately 75% and an increase in the peak contact pressures of approximately 235%** (Fig. 2).

The increased intra-articular contact stresses within the knee after meniscectomy are thought to 'overload' the articular cartilage, with associated biochemical changes, including loss of proteoglycan, disaggregation of proteoglycan, an increase in synthesis of proteoglycan and an increase in hydration.¹⁹ The macroscopic and microscopic signs of failure of articular cartilage after meniscectomy have also been demonstrated by animal models,^{19,20} ranging from fibrillation of the surface to necrosis and loss of the cartilage layer.

Radiological changes after meniscectomy

In 1948, Fairbank¹⁶ compared the radiological changes in 107 patients before and after meniscectomy. He observed formation of an anteroposterior ridge projecting downwards from the margin of the femoral condyle over the site of the old meniscus, generalised flattening of the marginal half of the articular surface of the femur, and narrowing of the joint space on the side of the operation (Fig. 3). When narrowing affects the lateral joint space, apparent widening of the medial compartment has been observed occasionally.¹⁶

Numerous studies have reported the prevalence of radiological changes after meniscectomy. However, direct comparison between these studies is difficult owing to the diversity of patients studied, the procedures performed, the duration of follow-up, the radiological criteria used, and the varying qualities of the studies themselves (Table I).²¹⁻²⁶

One of the more comprehensive accounts²⁷ examined 107 of 123 patients, 21 years after meniscectomy by clinical review and with weight-bearing radiographs, using gender- and age-matched controls. The relative risk for more advanced radiological changes, representing definite tibiofemoral osteoarthritis (OA), was 14.0 (95% confidence interval (CI) 3.5 to 121.2).

Opinion varies regarding a correlation between the radiological signs of degeneration and the actual clinical symptoms and outcome. Appel²⁸ noted that subjective complaints were not always in agreement with the radiological findings, and stated that "Patients with objective findings could be entirely without signs of roentgenologic OA or subjective complaints, or vice versa".

Scheller, Sobau and Bulow²⁹ reviewed 75 patients five to 15 years after arthroscopic partial lateral meniscectomy in an otherwise normal knee. Despite a high percentage of radiological changes, there was no significant correlation between these and the subjective symptoms or functional outcome. Conversely, other studies have found an association between radiological changes and clinical outcome. In a study of 159 patients 17 to 22 years after open meniscectomy, Roos et al³⁰ found that patients with only minor radiological changes recorded no significant differences for self-reported outcomes compared with those without any radiological changes. However, those with marked degenerative changes did have more self-reported pain, other symptoms in the knee, and limitation of function.

There is an increased risk of developing radiological changes after meniscectomy, and it appears

likely that the more severe changes, which tend to be seen with longer follow-up, correlate with poorer clinical results.

Open vs arthroscopic meniscectomy

Jackson and Dandy³¹ studied 107 total and 33 partial meniscectomies, reporting in 1975 that four operations had been performed through an arthroscope. Since Dandy introduced arthroscopy of the knee into the United Kingdom it has become a routine, widely accepted procedure.²⁵

In 1986, a retrospective review³² of 230 patients undergoing either open or arthroscopic meniscectomy found that arthroscopic surgery resulted in a significant reduction of hospital stay, and an earlier return to work and sport.

It is interesting to note that in 1980, Noble and Erat³³ stated that, in relation to arthroscopic surgery of the knee, “Much of the success with these time-consuming techniques appears to have been in North America. At the moment it is likely that only a minority of British surgeons will acquire that expertise with arthroscopy described by Jackson and Dandy (1976). Indeed, it is probable, in the current economic climate, that many will not even be able to acquire an arthroscope”.

Total vs partial meniscectomy

Since the advent of arthroscopic surgery, the development of suitable surgical instruments has enabled surgery aimed at resection of the minimum necessary amount of meniscal tissue to be performed. Partial meniscectomy is now a widely reported procedure, with many studies in the literature documenting the clinical and radiological outcomes.^{29,34–53} In a biomechanical study of partial and total medial meniscectomy in cadavers, Burke, Ahmed and Miller⁵⁴ found a linear correlation between the increase in peak stress on the joint surfaces of the tibia and the amount of meniscal tissue removed. Similar findings were confirmed by Ihn, Kim and Park.⁵⁵

In a canine study by Cox and Cordell⁵⁶ the degree of gross and microscopic changes in the articular cartilage was directly proportional to the amount of tissue removed. A number of studies have commented on the effects of partial *versus* total meniscectomy in humans.^{57–61} Hede et al⁵⁹ described the long-term results of patients undergoing partial or total meniscectomy. In this randomised prospective comparison of the two procedures, 200 patients were followed for a median period of 7.8 years. The function of the knee was inversely related to the amount of tissue resected.

Various authors have also found differences in outcome after partial meniscectomy, depending on the site of the lesion within the meniscus. Hede et al⁵⁹ observed lower knee scores after partial meniscectomy for posterior horn tears, compared with those with either anterior horn or bucket-handle tears. They also noted that preservation of the peripheral rim of the meniscus is essential to obtain the best long-term results. Similarly, Chatain et al⁵⁰ noted that resection of the posterior one-third or the wall of the meniscus predisposed to a poor radiological outcome.

Radial vs circumferential tears

One important point in the discussion of partial *versus* total meniscectomy was highlighted in 2001 by Hoser et al,⁵¹ who stated that “Many arthroscopic ‘partial’ meniscectomies may functionally represent a total meniscectomy. This may explain why the long-term clinical outcome may not be as good as anticipated”. The crucial issue here probably relates to the degree to which the circumferential collagen

fibres within the meniscal tissue are disrupted. Any break or discontinuity in these fibres caused by a radial tear will prevent the formation of the so-called 'hoop strains'⁶² that develop within the menisci as they are loaded, thus effectively defuncting the tissue. Horizontal or vertical circumferential tears may cause pain and lead to mechanical instability of a portion of the meniscus, but they will not disrupt the functional continuity of the circumferential fibres. Hence, the load-bearing and shock-absorbing functions of the tissue should be largely preserved.

Medial vs lateral meniscectomy

There are clear anatomical differences between the medial and the lateral compartments of the knee, and between the medial and lateral menisci. On the lateral side, the meniscus carries 70% of the load in the lateral compartment, whereas the medial meniscus carries only 50% of that of its compartment.¹ Also, in the sagittal plane, on the medial side the convexity of the femoral condyle and the concavity of the medial tibial plateau give some degree of congruity, even in the absence of the medial meniscus. On the lateral side, however, the convexity of the femoral condyle is mirrored by convexity of the lateral tibial plateau. Thus, in the absence of the meniscus, on the lateral side there will be a greater tendency towards point loading and an increase in peak contact pressures (Fig. 4).

Worse results have been reported after lateral than after medial meniscectomy.^{32,59,63–65} In a 30-year longitudinal study, McNicholas et al⁶⁵ found that after medial meniscectomy 80% of patients had good or excellent results at long-term follow-up, whereas only 47% had such an outcome after lateral meniscectomy.

The presence of pre-existing degenerative changes in the knee

Several authors have noted the potential influence on outcome of pre-existing degenerative changes in the articular cartilage at the time of meniscectomy. In 1970, Appel²⁸ observed an increase in the severity of the radiological signs of osteoarthritis at long-term follow-up in those patients who had pre-existing arthritic changes on their radiographs before operation.

Schimmer et al⁴⁷ found that the factor with the highest impact on long-term results following arthroscopic partial meniscectomy was damage to the articular cartilage. Although pre-existing damage did not influence knee function for several years after operation, patients with damage to the articular cartilage had increasing symptoms over time. After five years and more, only 62% of patients with cartilage damage rated excellent or good, compared with 95% of those with isolated meniscal tears and an intact joint surface.

Alignment of the knee joint

Varus or valgus deformity of the knee displaces the line of weight-bearing through the knee joint, increasing the load on the medial or lateral compartments, respectively. The normal mechanical axis of the leg runs from the centre of the femoral head, through the medial tibial spine to the centre of the talus. The tibiofemoral angle between the mid-medullary lines of the femur and tibia is approximately 7° in the normal leg.⁴⁵

A review of 210 patients ten to 22 years after meniscectomy⁶⁶ found that those with abnormal leg alignment showed significantly more degenerative changes in the knee. Covall and Wasilewski³⁷ found that after arthroscopic meniscectomy in knees where the tibiofemoral angle was 4° or more, 60% showed

no osteoarthritic progression at a mean follow-up of 5.4 years. However, in knees where the angle was less than 4° valgus (i.e. the knee was in varus), 7% had no change, 50% showed one grade change according to Fairbank's criteria,¹⁶ and 43% showed change of two or more grades. This result was described as highly significant ($p < 0.001$). Patients with varus knees also had significantly worse clinical outcomes. These results suggest a role for osteotomy in malaligned knees with meniscal damage.

Ligamentous instability

The incidence of meniscal tears is high in knees with ruptures of the ACL. Cerabona et al⁶⁷ found that 47 of 102 patients undergoing arthrotomy for primary repair of an acute tear of the ACL also had meniscal injuries.

Many studies have documented the poor results associated with meniscectomy in knees with deficiency of the ACL.^{37,45,63,68–70} Sherman et al⁷⁰ observed that meniscectomy hastened the progression of such knees towards arthritis. Burks et al⁴⁵ showed that patients undergoing partial meniscectomy in the presence of tears of the ACL had significantly worse radiological changes at a mean of 14.7 years than those undergoing partial meniscectomy with an intact ACL.

The consequences of meniscectomy may be exacerbated in the unstable knee by the combination of elevated contact stresses, with the contact areas moving abnormally over the joint surfaces, inducing pathological changes as a result of elevated shear stresses within the articular cartilage.

Patient activity levels

The results following meniscectomy may be influenced by athletic activity. Jorgensen et al⁶⁴ reviewed 147 athletes after meniscectomy for isolated meniscal injuries and found that radiological deterioration started after 4.5 years. After 14.5 years, 89% of athletes had radiological evidence of degeneration, and 46% had given up or reduced their sporting activity. These values are higher than would be expected for the general population.

Hoshikawa et al⁷¹ reported that none of 68 active patients had to give up sports at a mean of 4.5 years after meniscectomy. However, international-class athletes fared worse in both clinical and radiological evaluation than did recreational athletes. International-level volleyball players had particularly poor results.

Roos et al⁷² found a significant influence of the levels of sporting activity after meniscectomy. In 286 football players, the rate of arthritis in the knee was 1.6% in controls, 4.2% in non-elite players and 15.5% in elite participants.

Other patient factors: age, gender and weight

Some studies have suggested poorer outcomes after meniscectomy in older patients. Chatain et al⁵⁰ observed an odds ratio for the development of radiological degenerative changes of 5.0 in those over 35 years of age, compared with younger patients. In his paper in 1923, McNeill Love¹¹ stated: "As was to be expected, prognosis in the elder patients was less good than in the younger, for the power of recuperation diminishes with age and osteoarthritic changes are more prone to occur". However, Burks et al⁴⁵ found that age did not influence the results in their series of 146 patients followed up for 15 years after partial meniscectomy. Although the articular cartilage may be more vulnerable in older patients owing to lower fatigue strength,⁷³ such patients are likely to be less active, which may explain this lack of association in

some studies.

Tapper and Hoover¹³ noted a much lower proportion of excellent and satisfactory results in women than in men. Johnson et al⁶³ found significantly worse recovery in females after total meniscectomy, and Roos et al³⁰ showed that after meniscectomy women had significantly more pain and limitation of function in sport and recreation than did men. However, Allen et al,⁶⁶ Chatain et al⁵⁰ and Fauno and Nielsen³⁸ failed to identify any difference in outcome between men and women.

Scheller et al,²⁹ in a long-term follow-up of patients with a partial lateral meniscectomy in an otherwise normal knee, demonstrated a correlation between a high body mass index (BMI) and a lower percentage of excellent/good results. However, no similar association was seen with the radiological results. Bonamo et al³⁶ and Roos et al²⁷ failed to show any correlation between BMI and outcome after meniscectomy.

In defence of the meniscus

A proportion of meniscal tears may heal, either on their own or with the help of various repair techniques. Some tears may cause little or no symptoms as long as they remain mechanically stable. The ability of meniscal tissue to heal is probably closely related to its blood supply. At birth, the whole meniscus is vascularised.⁷⁴ However, an avascular area soon develops in the inner circumference of the meniscus, and in the second decade blood vessels are seen only in the outer third. This progressive loss of vascularity may be due to weight-bearing and knee movement. Arnoczky and Warren⁷⁵ performed a complete mid-portion transection of the medial meniscus in 15 canine knees. There was evidence of healing, as shown by the formation of a fibrovascular scar that originated from the peripheral synovial tissues. However, incisions in the inner avascular portion of the meniscus failed to heal.

Meniscal tears are often classified according to the location of the tear relative to the blood supply of the meniscus. With a 'red-red' tear, both the peripheral and inner margins have a functional blood supply and are reported to have the best prognosis for healing.⁷⁶ The 'red-white' tear has vascularised tissue on the peripheral side and avascular tissue on the inner side.⁷⁶ The 'white-white' tear is completely in the avascular zone and is least likely to heal.^{75,76}

Noble and Erat³³ reported on 250 patients scheduled for meniscectomy. Of those called in for operation, 50 did not undergo any procedure. Of these, 35 had spontaneously improved while awaiting surgery, ten failed to attend, and five were treated conservatively.

In a retrospective study of 3612 arthroscopic procedures, Weiss et al⁷⁷ identified 80 meniscal tears that had been assumed to be stable and which were therefore left alone. Of these, 70 were vertical longitudinal tears and ten were vertical radial tears. From this group, 52 patients were followed up for between two and ten years, and only six subsequently needed an operation. A further arthroscopy was performed on 32 patients at a mean of 26 months after the original arthroscopy. Of the longitudinal tears originally seen, 17 of 26 had healed; none of the six radial tears had healed, and one had extended. The authors concluded that a stable vertical longitudinal tear in the peripheral vascular zone of the meniscus has great potential for healing and should be left alone unless it is the only abnormality found and is causing symptoms that justify intervention.

In 1980, Goodfellow⁷⁸ published an editorial in the British edition of the *Journal of Bone and Joint Surgery* entitled "He who hesitates is saved". He stated that "Meniscectomy is only justifiable if a

meniscus is causing more trouble than it is worth, and that is a value judgement which, like much else in clinical surgery, must be taken on inadequate evidence”.

Meniscal repair

Over recent years there has been great interest in avoiding meniscectomy wherever possible, and repair has grown in popularity.

The first meniscal repair was performed in 1885 by Annandale, and was reported in the *British Medical Journal*.⁷⁹ A 30-year-old miner had felt something give within his knee while kneeling, followed by an effusion with subsequent pain and locking. An arthrotomy showed that the medial meniscus “was completely separated from its anterior attachment, and was displaced backwards”. The torn meniscus was repaired with three chromic catgut sutures, and the patient was “dismissed cured”.

Techniques of open,^{80,81} inside-out,^{82–84} outside-in^{85,86} and all-inside arthroscopic repair^{87,88} have been described, and each has its merits.⁸⁹ The results of repair have been encouraging. For example, Kotsovolos et al⁹⁰ described an all-inside repair system using two polymer suture bar anchors with a pre-tied self-sliding knot of braided poly-ester suture. At a mean follow-up of 18 months, just over 90% of 58 meniscal repairs were clinically successful, with absence of joint-line tenderness, locking or swelling, and a negative McMurray test.

Despite recent advances, however, a large proportion of meniscal tears observed at arthroscopy remain irreparable, and partial, subtotal or even total meniscectomy is often necessary, regardless of the recognised consequences. The evidence presented in this review supports further work to improve treatment, exploring techniques such as meniscal allografting, enhancement of the healing response, tissue engineered constructs, or perhaps meniscal implants.

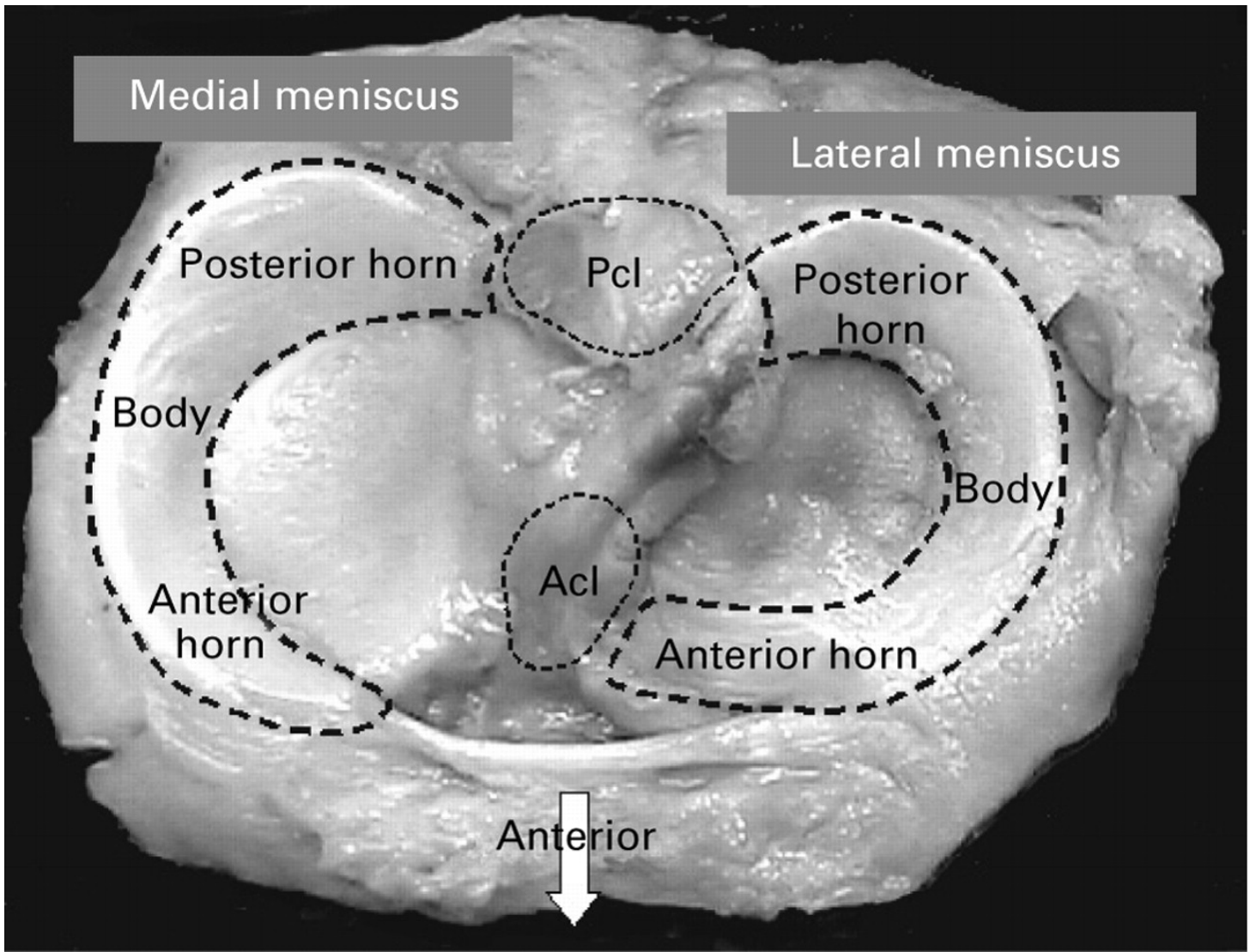


Fig. 1

The menisci of the knee as seen from above on a cadaveric tibial plateau (Pcl, posterior cruciate ligament; Acl, anterior cruciate ligament).

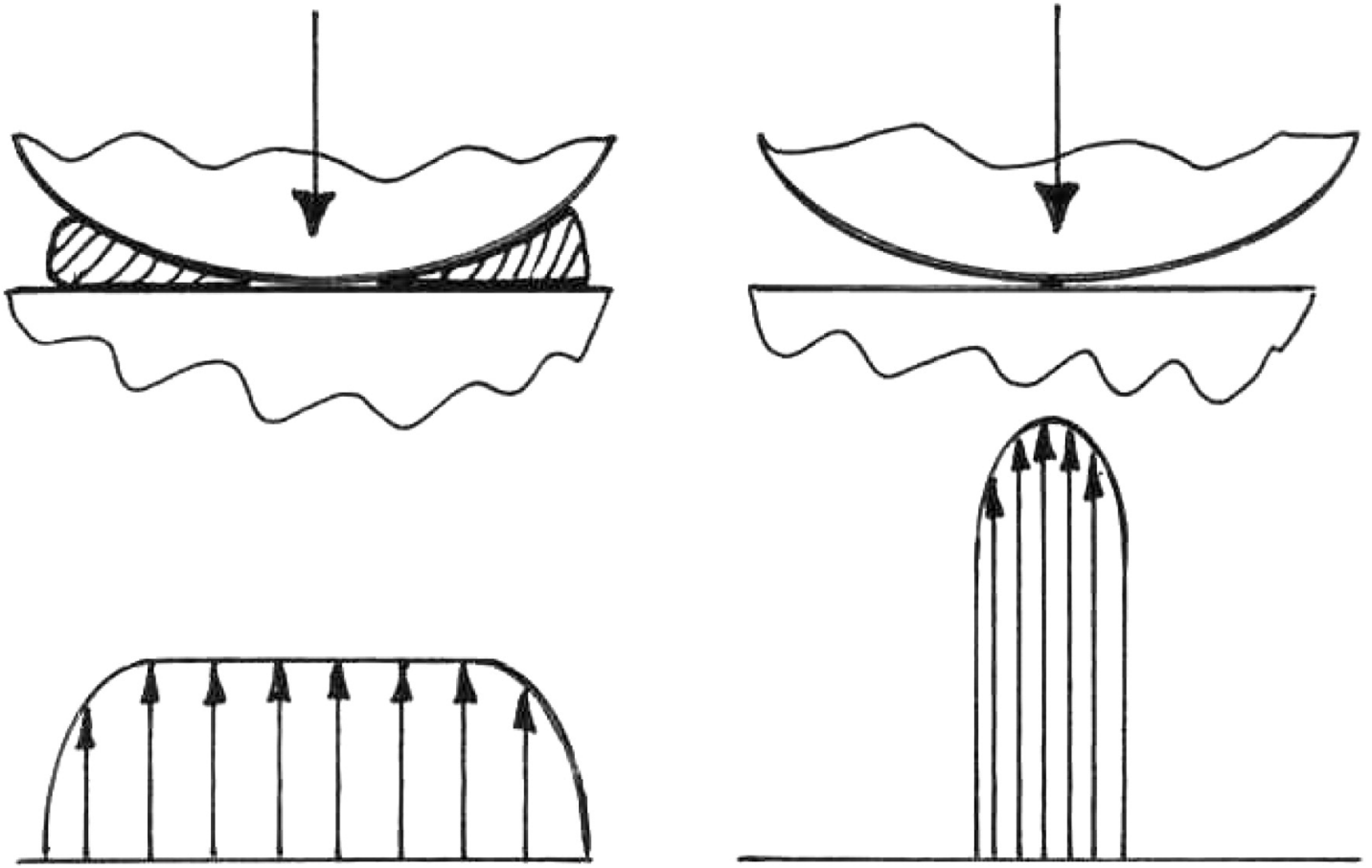


Fig. 2

Diagram demonstrating the focally increased peak contact pressures that result from meniscectomy.



Fig. 3

Anteroposterior radiograph of a right knee showing medial compartment osteoarthritis.

Medial side



Lateral side

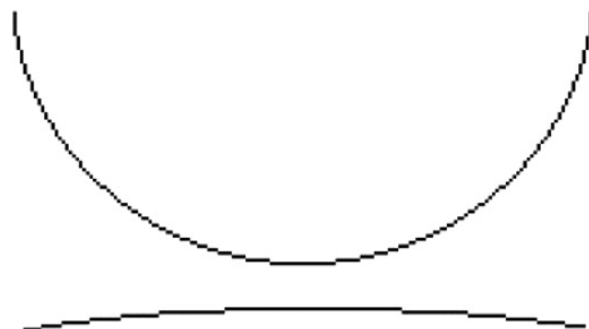


Fig. 4

Diagrammatic representation of different geometries of medial and lateral compartments in the sagittal plane without menisci, leading to probable differences in joint congruity.

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