

## KNEE JOINT CHANGES AFTER MENISCECTOMY

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This paper records an investigation of changes found in the knee joint at intervals ranging from three months to fourteen years after meniscectomy. In a search of the literature only one reference to these changes has been found. Vandendorp, Bastien, and Vandecasteele (1939-40) observed in a few subjects that there was narrowing of the joint space and broadening of the femoral and tibial condyles on the operated side of the joint, but they offered no explanation of their findings.

### RADIOLOGICAL STUDY

After excluding all cases with definite osteoarthritis, a comparison was made between the pre-operative and post-operative X-ray films in one hundred and seven cases of meniscectomy. Owing to difficulty in securing identical views on separate occasions, the changes to be described were accepted as convincing only because they were seen repeatedly; and occasionally a film of the normal knee joint provided better comparison. The changes noted, alone or in combination, were of three types: formation of an antero-posterior ridge projecting downwards from the margin of the femoral condyle over the old meniscus site (Figs. 1 and 2); generalised flattening of the marginal half of the femoral articular surface—a reaction similar to but more diffuse than the ridge (Figs. 3 and 4); narrowing of the joint space on the side of operation (Figs. 5 and 6) which, after lateral meniscectomy, was occasionally accompanied by apparent widening of the opposite side of the joint; in three patients this was sufficient to cause symptoms suggestive of mild valgus strain of the knee. The lateral views showed nothing of significance; nor was any change observed in the tibia apart from slight sharpening of the articular margin, insufficient to be described as osteoarthritis. It must be noted that the femoral ridge may be seen even before operation, particularly in cases with long-standing lesions of the meniscus, and sometimes in apparently normal joints. The changes have been seen within five months of operation on many occasions, but they tend to become more obvious with the passage of time. No correlation was found between clinical and radiographic findings, many knee joints with the most marked radiographic changes being functionally perfect. The frequency of such changes after medial and lateral meniscectomy was:

	Total cases	No change	Ridge	Narrowing	Flattening
Medial meniscectomy	80	33 per cent.	43 per cent.	32 per cent.	18 per cent.
Lateral meniscectomy	27	50 per cent.	7 per cent.	40 per cent.	17 per cent.

Narrowing plus flattening were the commonest changes found in combination.

### INVESTIGATIONS

It is submitted that these changes result chiefly from loss of the weight-bearing function of the meniscus—a function which has not been accepted universally. Before enlarging on the problem two points must be emphasized. 1) If the normal meniscus is to take part in weight-bearing it can do so only if there is a force which prevents it from slipping away like an orange pip squeezed between the fingers. The peripheral attachments are loose and they are not designed to provide this counter-force, but there is another retaining mechanism which will be described later. 2) The elasticity of articular cartilage shows certain peculiarities (Hirsch 1944). Articular cartilage is perfectly elastic only for small loads applied for a very short time. If the load is maintained, deformation (*i.e.*, compression) continues slowly, and is not complete even after half an hour (Fig. 7). Recoil on removing the load has similar characteristics: the longer the load has been maintained the smaller is the immediate rebound

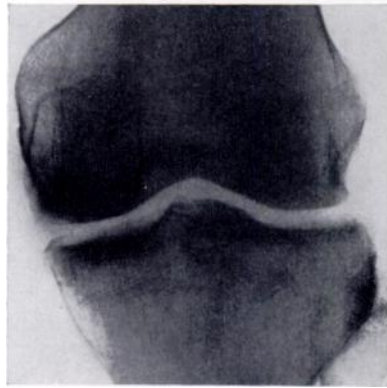


FIG. 1



FIG. 2

Patient, aged forty years, before operation (Fig. 1) and six years after removal of the medial meniscus, showing formation of a ridge from the margin of the femoral condyle (Fig. 2).



FIG. 3



FIG. 4

Patient, aged thirty-six years, before operation (Fig. 3) and seven years after removal of the medial meniscus, showing flattening of the femoral condyle (Fig. 4).



FIG. 5



FIG. 6

Patient, aged twenty-five years, before operation (Fig. 5) and five months after removal of the lateral meniscus, showing narrowing of the joint space laterally, and some widening medially (Fig. 6).

and the longer the gradual recovery phase; while if the load has been too great or too prolonged recovery is never complete. This is not the behaviour of a homogeneous substance. The structure of articular cartilage, with its fibrillar arcades (Benninghoff 1922, 1925), and the fact that local compression was seen to cause exudation of fluid from its surface, suggested that its elastic peculiarities might be comparable to those of a sponge. By using a simple

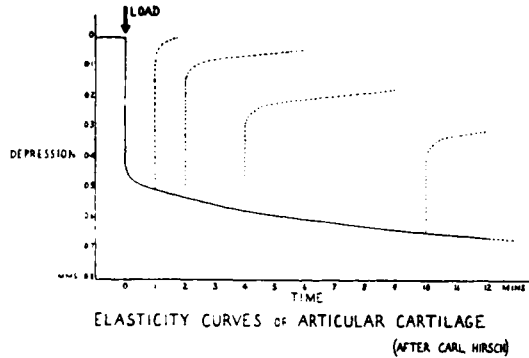


FIG. 7

The dotted lines represent recovery curves when the load is removed after increasing intervals.

on the knee after standing for a few minutes; 3) with full weight on the limb at the end of the day. In only one of seven subjects was the first view strictly comparable with the others because the degree of rotation and of extension both tend to alter slightly when weight is borne. By measuring the joint space in each view it was shown that the space narrowed by approximately one millimetre when weight was applied; and that by the end of the day it narrowed by another millimetre. Thus, as might be expected from the elasticity experiments, progressive compression of articular cartilage had occurred (Figs. 9 and 10).

A micrometric survey was then made of those parts of the femoral and tibial articular surfaces which are normally apposed in full extension, using an apparatus devised with the generous aid of Professor Thom, Professor of Engineering at Oxford (Fig. 11). By means of the lathe traversing, to which it was bolted, the gauge could be moved in the horizontal plane either sagittally or coronally for known distances. It recorded any vertical movement of the hemispherical pelotte, which rested on the articular surface and slid over it as the gauge was moved. The bone was firmly screwed to the base block. By taking gauge readings at each millimetre shift of the traversing gear it was possible to plot the curvature of a regular series of sections, sagittal and coronal, on a very large scale. These have been arranged to give perspective views of the apposed condyles (Figs. 12 to 15). Two knees were thus surveyed. Both were macroscopically normal and came from autopsy cadavers of women aged thirty and thirty-three years. The figures show how surprisingly incongruous are the joint surfaces, particularly in the sagittal plane, where much of the medial tibial condyle is almost flat and the lateral tibial condyle actually convex.

Fig. 16 represents diagrammatically a sagittal section through the lateral compartment of the knee joint. It is evident that until the articular cartilage has been compressed the femur

modification of the elasticity apparatus designed by Bär (1926), strikingly similar curves were in fact produced from sponge rubber immersed in glycerin (Fig. 8).

With this behaviour in mind, and in order to observe the degree of compression which occurs in the living joint, radiographs were taken of normal knee joints in full extension and in the upright position. Very careful precautions were employed to obtain identical views for three exposures: 1) in the morning before any weight had been placed on the limb, the muscles gently bracing the knee joint into extension, and all weight being on the other limb; 2) with full weight

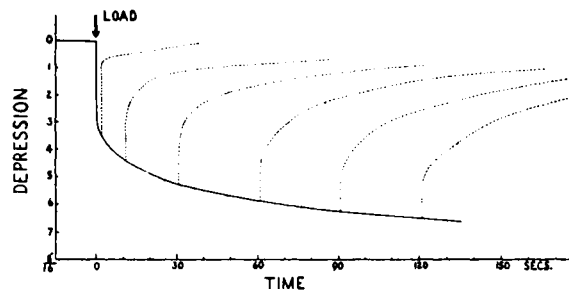


FIG. 8

Recovery curves of sponge rubber in glycerin for comparison with Fig. 7.

cannot bear upon the meniscus as a whole. Fig. 17 shows the effect of such compression. Tracings of apposed sagittal sections of the lateral femoral and tibial condyles were superimposed so that their intersections took place at a distance equal to that between the central margins of the meniscus, in this case twelve millimetres. The compression was therefore just sufficient to bring the femur down on to the meniscus. The articular cartilages were then sharing a central compression of one millimetre, which by the same method could be shown to be approximately the same in the medial compartment of the joint.

As compression increases, whether from sudden strains or in consequence of normal weight-bearing throughout the day, the circumference of the meniscus must be forced centrifugally. But in so far as the two ends of the meniscus are firmly attached to bone this force is resisted by rising tension in the stretched and elastic fibrocartilage. The greater the degree of joint

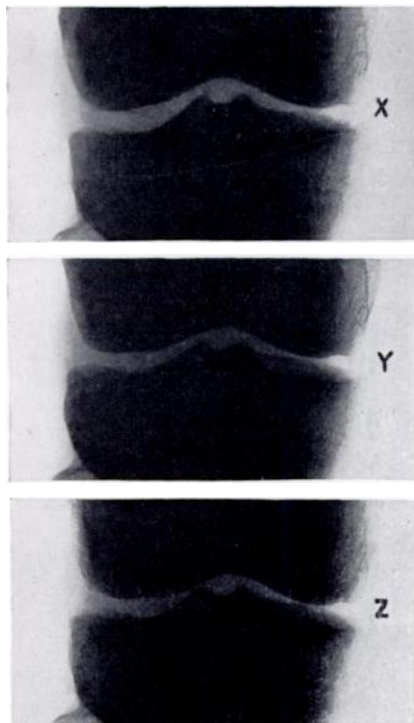


FIG. 9

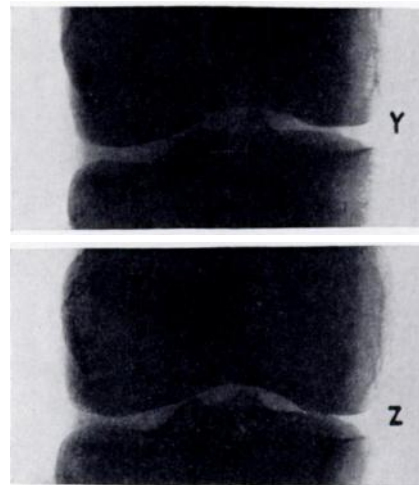


FIG. 10

Fig. 9 shows a normal knee joint after a night's rest without weight-bearing (X); after weight-bearing for two minutes (Y); and weight-bearing at the end of the day (Z).

Fig. 10 shows a normal knee, weight-bearing in the morning (Y) and in the evening (Z).

compression, the greater the circumferential tension in the meniscus. It is submitted that this tension resists extrusive forces and enables the meniscus to share in weight-bearing. That the tension is real was confirmed by stripping a knee joint of the outer soft tissues, while leaving the cruciate ligaments intact and the menisci in position but attached only by their central ends. In full extension the menisci remained slightly mobile until compression was applied, when the periphery of the menisci at once became hard and tense.

#### DISCUSSION

Meniscectomy must therefore result in relative overloading of the articular surfaces on that side of the joint, with increasing compression of the cartilage. But narrowing of the joint space after operation was seen in X-ray films of the recumbent patient, and if such narrowing is permanent, and radiographically demonstrable, it must be due either to structural

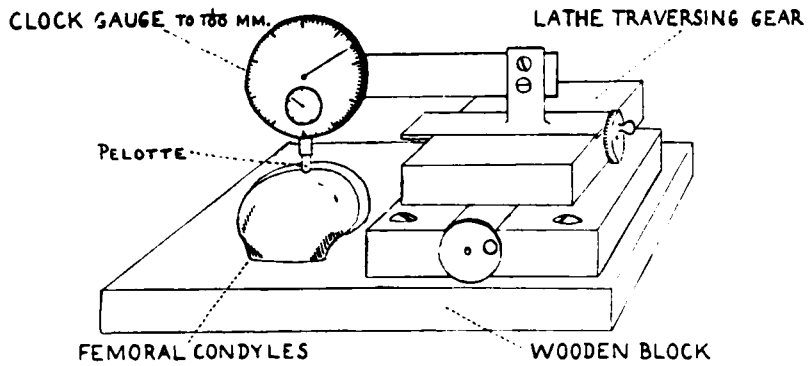


FIG. 11

Apparatus for articular survey (see text).

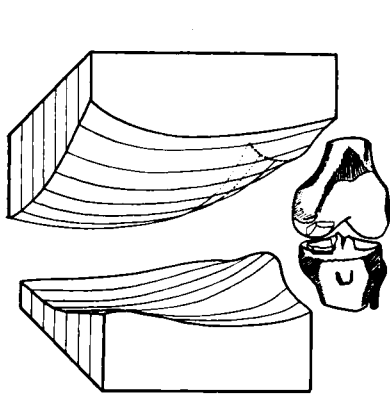


FIG. 12

Coronal section outlines of the medial condyles—interval between each section 3 mms.

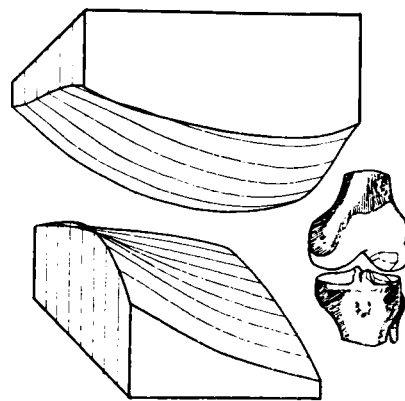


FIG. 13

Coronal section outlines of the lateral condyles—interval between each section 3 mms.

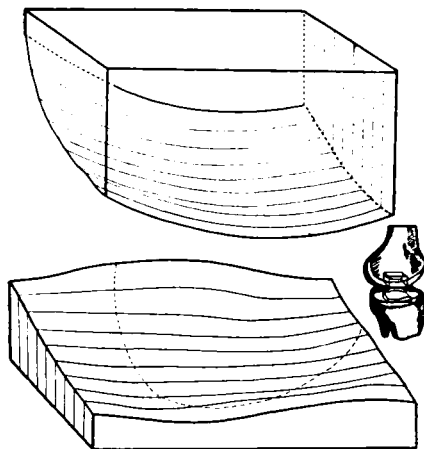


FIG. 14

Sagittal section outlines of the medial condyles—section intervals 2 mms. The dotted line on the tibial surface represents the central margin of the meniscus.

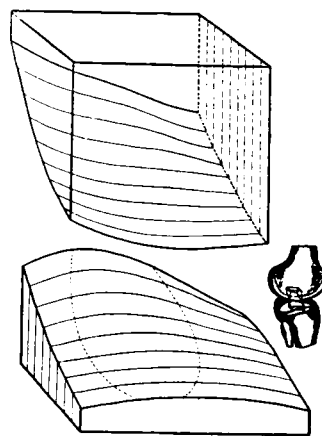


FIG. 15

Sagittal section outlines of the lateral condyles—section intervals 2 mms. The dotted line on the tibial surface represents the central margin of the meniscus.

changes in the articular cartilage which impair the power of recoil, or to actual loss of tissue. The method by which loss of articular cartilage from normal wear and tear is replaced, if it is replaced at all, is still in doubt. But the work of Elliott (1936) suggests that in the adult there is amitotic cell division occurring very close to the surface. The speed of this division is controlled by: 1) a nutritional factor which accounts for an increasing rate of cell division as the articular surface is approached; and 2) a mechanical factor, possibly associated with friction, which inhibits cell division and completely arrests it at the surface itself. Elliott's work was done on experimental animals and so far as can be ascertained it has not yet been confirmed in man, although this writer has made preliminary investigations. MacConaill (1932) stressed the importance of the meniscus as a lubricating mechanism and stated that loss of the meniscus caused a 20 per cent. increase in friction. It is reasonable to suppose that both nutritional and mechanical factors will be affected adversely when cartilage is overloaded, and the resulting interference with tissue replacement may account for the marked narrowing.

Flattening and ridge formation over the former site of the meniscus present another problem. These changes appear to be due to reaction in the overlying bone which is no longer subject to the pressure of the meniscus, although changes in the synovial blood supply at the margin may well be significant. We know that bone which is subjected to excessive pressure undergoes atrophy, and in the knee joint this may be seen in the lateral femoral condyle overlying a cystic meniscus. The condyle reacts in the opposite manner when normal pressure is removed; the mechanical effect is that of spreading the load of body weight.

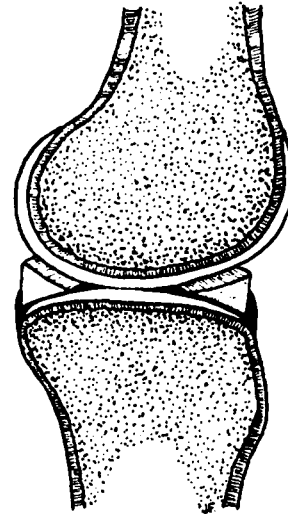


FIG. 16  
Sagittal section to show that the femur cannot rest on the meniscus until compression of articular cartilage has occurred.

EFFECT ON MENISCUS  
OF JOINT COMPRESSION

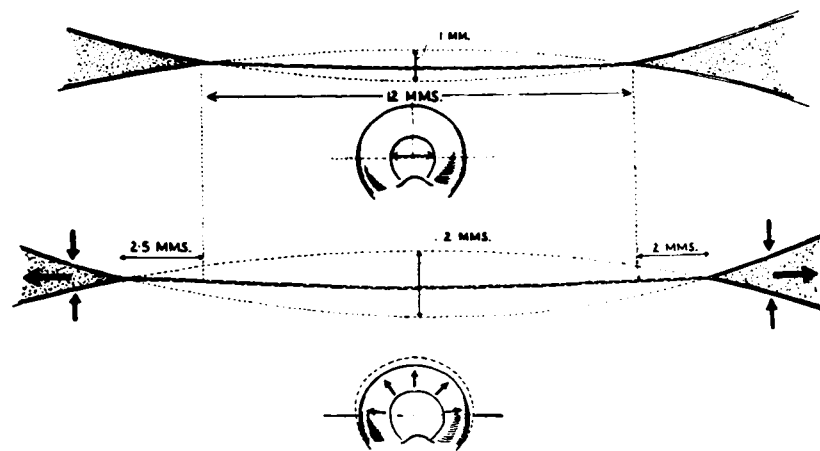


FIG. 17

Superimposed tracings of sagittal sections of the tibial and femoral condyles to show the effect of joint compression in producing centrifugal displacement of the meniscus (for explanation see text).

The final problem is why the findings should be inconstant. There appear to be two possible explanations: 1) variations in the reserve or safety factor of individual joints about

which we know so little; 2) variations in the speed and completeness of regeneration of the meniscus. In this series, the results of investigation by arthrography have been inconclusive; a knee with no changes whatever in the articular cartilage or bone was shown to have almost no replacement of the meniscus, while another with ridge formation had fibrous replacement of the meniscus almost to the normal size. Arthrograms also suggested that the ridge consists solely of bone and that the articular cartilage may still have an even and normally curved surface, because the thickness of the cartilage diminishes rapidly as the apex of the bone ridge is approached. It is worth remarking that in dogs, Bruce and Walmsley (1937) found that regeneration of an excised meniscus was still progressing and not yet complete even after five months, while Pfab (1927, 1928), Dieterich (1931), and King (1936) found evidence of degenerative changes in the overlying femoral condyle.

#### SUMMARY AND CONCLUSION

Changes in the knee joint after meniscectomy include ridge formation, narrowing of the joint space, and flattening of the femoral condyle. Investigations suggest that these changes are due to loss of the weight-bearing function of the meniscus. Meniscectomy is not wholly innocuous; it interferes, at least temporarily, with the mechanics of the joint. It seems likely that narrowing of the joint space will predispose to early degenerative changes, but a connection between these appearances and later osteoarthritis is not yet established and is too indefinite to justify clinical deductions.

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