PATELLO-FEMORAL JOINT MECHANICS AND PATHOLOGY

2. CHONDROMALACIA PATELLAE

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Two distinct lesions affect the articular cartilage of the patella. Surface degeneration occurs particularly on the odd facet; it is age dependent, often present in youth and it becomes more frequent with increasing age. It probably does not occasion patello-femoral pain in youth, but may predispose to degenerative arthritis in that joint in later years and is regarded as a consequence of habitual disuse.

The term "basal degeneration" is used to describe a lesion in which there is fasciculation of collagen in the middle and deep zones of cartilage without, at first, affecting the surface. It was found astride the ridge separating the medial from the odd facet in twenty-three adolescents who had complained of prolonged patello-femoral pain. They were treated by excision of the disc of affected cartilage, with relief of pain in most cases.

The pathogenesis of basal degeneration is related to the functional anatomy of the patella.

Although the term chondromalacia patellae has been used in the title of this paper to convey the idea of the familiar syndrome of pain behind the knee-cap, we find it necessary at the outset to reject this use of the term and the assumptions inherent in it. Here we will describe the clinical syndrome as "patello-femoral pain"; and reserve other terms to describe the pathological processes in articular cartilage which may or may not cause that syndrome.

We will attempt to define two distinct disorders which commonly affect the cartilage on the patella and seek to relate them to the occurrence of patello-femoral pain in youth and in maturity. We believe that the frequent co-existence of these two pathologies has obscured the precise recognition of either of them.

PATELLO-FEMORAL PAIN: THE SYNDROME

The patello-femoral pain syndrome has been well described by many authors, notably Wiles, Andrews and Devas (1956) and Ficat (1970). Its features include pain in the knee cap, felt when the knee functions under load in flexion, typically when going up and down stairs. Prolonged sitting with the knee flexed causes pain, which is relieved by extension of the joint. Two signs usually accompany these symptoms. Firstly, when with the knee extended and the quadriceps relaxed the patella is pushed distally and pressed against the femur the typical pain is experienced. Secondly, the medial part of the patella's articular surface is tender on direct palpation.

Crepitus is usually present, occurring as a symptom and demonstrable as a sign. However, there is no close association between crepitus and pain, and as noisy creaking is often present in joints which are otherwise asymptomatic it is not of much diagnostic significance.

Patello-femoral pain occurs at all ages. It is a common complaint in adolescents and young adults, and in our experience girls outnumber boys in a ratio of 3:2. In this group the classical signs of arthritis are usually lacking: joint effusion is rare, and there is no limitation of joint movement. The disorder is often bilateral and the symptoms are frequently remarkably persistent, continuing over several years without getting either better or worse. All authorities agree that many recover spontaneously, and there is little evidence to suggest that the syndrome in youth portends the development of patello-femoral osteoarthritis in later years. The only follow-up study on young patients with this disorder is that of Karlson (1939), who examined seventy-one men diagnosed one to twenty-one years previously. Only seven of these patients showed early osteoarthritic changes and none had severe changes.

In the fourth and fifth decades patello-femoral pain is less common, and when present is usually attributable to a contusion or fracture of the patella. In old people patello-femoral pain is again common as a more or less predominant feature of degenerative arthritis of the knee joint, and in this group the classical signs of osteoarthritis—effusion, limitation of joint movement and radiological signs—are almost always present. In this group the signs and symptoms tend gradually to increase.

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PATHOLOGY OF THE ARTICULAR CARTILAGE OF THE PATELLA

There follow some observations upon the pathological changes which have been observed in the articular cartilage of the patella, without at first drawing conclusions as to their relevance to the clinical syndrome of patello-femoral pain.

Age-dependent surface degeneration—This term is intended to describe that sequence of degenerative changes which has been observed to develop in some parts of most human joint surfaces as an almost inevitable consequence of ageing (Heine-Rostock 1927; Harrison, Schajowicz and Trueta 1953; Goodfellow and Bullough 1967; Byers, Conteponi and Farkas 1970). It is called age dependent because the lesion is encountered more frequently and in a more advanced form in middle-aged joints than in those of young adults, and becomes almost the rule in old age.

It is a surface degeneration, because the first observable changes affect the articular surface of the cartilage, and the lesion may progressively deepen until all the layers of the cartilage are affected down to the subchondral bone plate. It has been amply demonstrated in the elbow, the knee and the hip joints that such changes occur in each of these joints in a more or less regular pattern, some parts of the joint facets being almost always affected and others almost as regularly escaping. It has been further demonstrated in the elbow and the hip that the areas so affected are those which, because of joint geometry and human habits, are seldom used. Within such habitual non-contact areas early surface degenerative changes are observed even in youth. In areas of habitual contact they are less commonly encountered.

The minute anatomy of the various stages of this process has been described elsewhere (Bullough and Goodfellow 1968). Their sequence and a suggested terminology to assist in a more precise description of cartilage lesions are shown diagrammatically in Figure 1.

The cartilage of the human patella demonstrates this lesion very frequently. Owre (1936) found flaking and fissuring of some part of the patellar cartilage in eighteen of thirty-two subjects aged twenty to twenty-nine years. The incidence increased steadily thereafter with increasing age, and the lesion was present in all but one of sixteen subjects aged sixty to eighty years. Wiles et al. (1956) recorded that nearly all adult knees showed some evidence of pathological changes, and remarked that "these are generally restricted to a small part of the patella". They noted that the medial border of the medial facet was the most frequent site for such cartilage changes, and that when degeneration was severe osteophytes appeared along the medial margin of the patella. Outerbridge (1961) observed the state of the patellar cartilage at meniscectomy in 101 patients, and recorded "surface fissuring and fragmentation" on the medial patellar facet in four of twelve subjects aged twelve to nineteen, eleven of seventeen subjects aged twenty to twenty-nine and with increasing frequency at each decade, twelve of fifteen subjects aged fifty to sixty-nine years. Emery and Maechim (1973) have provided the most detailed description of the topographical distribution of surface degenerative changes in cadaveric patellae. They found overt fibrillation in almost every subject they examined, limited in young subjects to the articular margins and to a specific area on the medial margin of the medial facet, and they remarked that at this site the lesion did not progress to ulceration even in old subjects. In contrast, fibrillation elsewhere upon the patella's surface appeared commonly in middle-aged subjects, and at these sites it became progressively more common and more severe with increasing age.

The authors' experience at operation and at necropsy confirms that surface flaking on a specific part of the medial facet of the patella is often seen in youth and is the rule in adult life. We would, however, be more precise about the area affected. When that area is still restricted it is almost always limited to the "odd facet" of the patella, an area of cartilage defined by a distinct vertical ridge which separates the facet from the medial facet proper (see previous paper and Figures 2 and 3). Furthermore, when the affected area is more extensive it has always included the odd facet within it.

There is then, on the patellar cartilage, a well documented pattern of age-dependent surface degeneration. Its histological and morphological characteristics differ in no way from such changes recorded in other joints.

It is to be noted that this lesion has been recorded,
in all the reports cited above, as a chance finding at necropsy or at arthroscopy done for reasons unconnected with the patello-femoral articulation.

There is no evidence that this lesion causes patello-femoral pain. Indeed there is good reason to believe that it does not. Since it is found in half the youthful population and in nearly all old people it must be assumed to be a painless lesion, and one that, in itself, does not significantly prejudice joint function. Nor does it constitute evidence to the contrary when such a lesion is observed in a patient suffering from patello-femoral pain. The necropsy studies have provided background information on the expected state of the normal patella in each decade. Some other defect must be sought to explain patello-femoral pain.

We attribute the localisation of the lesion to the "odd facet" of the patella to the particular circumstances of the cartilage in that area, constituting as it does an area of habitual disuse (see previous paper).

**Patello-femoral osteoarthritis**—Our dismissal, in the previous paragraphs, of age-dependent surface degeneration as the explanation for patello-femoral pain in youth, need not imply that it is altogether without significance in the long term. The theory has been propounded elsewhere that such changes are usually of little consequence because the circumstances which occasion them, namely relative disuse of an area of cartilage, also render them inconsequential (Bullough and Goodfellow 1968). However, the unitary nature of the collagen framework on an articular facet implies that degeneration at any site may prejudice the load-bearing function of it all. When the cartilage in adjacent habitual contact areas degenerates the lesion spreads across the medial facet of the patella, presaging the development of the secondary changes which result from failure of the load-bearing capacity of cartilage. In this sense age-dependent surface degeneration may be a precursor of osteoarthritis. The observations of Emery and Meachim (1973), referred to above, distinguishing as they do a non-progressive degeneration on the odd facet from progressive lesions elsewhere on the patella's surface, invite this explanation. Heine-Rostock (1927) showed in a post-mortem study that those joints which most frequently demonstrate surface changes in youth and middle age are those which most often develop frank osteoarthritis in old age. The high frequency of surface changes on the young patella is matched by a high frequency of osteoarthritis in old age.

In summary, we suggest that surface degeneration changes, though they will very frequently be met with at arthroscopy, usually limited to the odd facet, do not cause patello-femoral pain until they have progressed to exposure of bone upon an area of habitual patello-femoral contact (medial and lateral patellar facets). The process is a very slow one and seldom occasions pain earlier than late middle-age. When it does become symptomatic a radiograph reveals the familiar changes of osteoarthritis of the joint.

**Basal degeneration**—This term is proposed to describe a lesion of articular cartilage which is essentially different from that described above. It is a disorder of the deep layers of the cartilage which only involves the surface layer, if it does so at all, late in its development. The specimens to be described all came from the knee joints of adolescents who complained of persistent patello-femoral pain.

The diagram in Figure 4 demonstrates three stages of this lesion. When the cartilage is in the state described in the diagram as "fasciculation (stage I)" the articular surface is smoothly intact and the disorder can only be detected by palpation. The cartilage has then an appreciably spongy consistency and exhibits what can be fairly described as "pitting oedema". If an area of cartilage
thus affected is separated from the surrounding normal cartilage by a circumferential incision; the disc of material thus isolated can be prized off the underlying bone with a rougine. Figures 5 to 7 show a disc of fasciculated cartilage taken in this way. The articular surface (Fig. 5) is glistening and smooth, the deep surface (Fig. 6) is impossible to elevate such cartilage from the bone by the method described. A sharp tool must be used, and the resulting surface is then, of course, a smooth one.

Fissuring of the deep surface of fasciculated cartilage after erasure from the bone is, we believe, evidence of lack of cohesion between the thick collagen bundles, and

![Diagram showing stages in the lesion of basal degeneration.](image)

**Fig. 4**
Stages in the lesion of basal degeneration.

![Three photographs of a disc of cartilage approximately 1 centimetre in diameter, showing fasciculation (Stage 1).](image)

**Fig. 5**
Articular surface.

**Fig. 6**
Deep surface.

**Fig. 7**
Cut margin.

The disorder can be localised at operation only by palpation with a blunt seeker, and its margins are therefore somewhat indistinct. Nevertheless, we have been able to determine two sites of predilection. The first is

patterned with fissures and the cut margin (Fig. 7) demonstrates thick fascicles of collagen material vertical to the articular surface. It must at once be admitted that the fissures are artefacts, created during the process of prizing the material off the bone, but they are artefacts which can only be produced when cartilage is in the state of fasciculation. We have attempted to prepare discs of normal and surface degenerated cartilage for comparison, but it is mechanical proof that the cartilage was being held together by the intact tangential fibres at the articular surface and by the insertion of the vertical bundles into the subchondral bone beneath.
in an area about 1 centimetre in diameter astride the ridge which separates the odd facet from the medial facet. The second area straddles the inferior part of the central ridge which separates the medial from the lateral patellar facets. The areas are close together and are sometimes confluent.

Figures 8 and 9 show a patella excised from an adolescent who complained of persistent patello-femoral pain. The cartilage lesion represents, we believe, the consequences of rupture of the tangential surface fibres in fasciculated cartilage (Stage 2 in Fig. 4). The lesion lies astride the ridge between the medial and odd facets as the bisected specimen demonstrates.

The minute anatomy of this cartilage as seen through the dissecting microscope reveals fasciculation with intact surface fibres in some parts (Fig. 11), and the consequences of rupture elsewhere (Fig. 12). Figure 10 shows normal cartilage for comparison.

One other lesion, apparently intermediate between the two stages of fasciculation just described, has been observed. Figures 13 and 14 show a blister-like disorder, measuring 6 millimetres in diameter, of the cartilage on the crest of the ridge between the medial and odd facets of an adolescent whose joint was explored because of persistent patello-femoral pain. A disc of cartilage surrounding it was erased as previously described. Its histological characteristics are shown diagrammatically in Figure 4, where it is placed between the two stages of fasciculation, since we do not know whether it represents a phase immediately before rupture or, perhaps, a process of healing after rupture.

HISTOLOGICAL FEATURES
The lesion described above as fasciculation has been characterised by its naked eye appearances, by its site upon the patella's surface and by its regular discovery within the knees of adolescents who underwent arthroscopy for persistent patello-femoral pain. It was hoped that microscopy would reveal equally distinctive features
in the matrix and the chondrocytes to allow a definitive description of the lesion to be offered. In fact no unique features were found that would allow a diagnosis to be made from the histology alone. Nevertheless, some of the appearances are of interest.

Some specimens which appeared fasciculated showed lakes of featureless basophilic material lying between the thick bundles of collagen which constituted the fascicles observed with the naked eye. In all fasciculated specimens the ground substance stained less well with P.A.S. than in normal cartilage. Chondrocyte proliferation was observed in the frond-like material of the more advanced lesions, and in some there was evidence of attempted repair by immature fibrous tissue.

Figure 15 shows the blotchy appearance of the stained matrix, and rupture of the cartilage material in its mid zone, and yet the articular surface remains intact.

Figure 16 is a section cut through the edge of the blister-like lesion shown in Figures 13 and 14, and shows that the blister consists of a plug of unorganised fibrous tissue within a defect in the cartilage. The walls of the defect are remarkably clear-cut and consist of histologically normal cartilage.

**THE SIGNIFICANCE OF BASEL DEGENERATION**

The lesion just described was found to be present in one or other of its forms upon the ridge which separates the medial from the odd facet in twenty-three young patients (age range fourteen to twenty-seven), who complained of patello-femoral pain. They had all suffered pain for more than two years when submitted to arthrofomy. During the period when these patients were treated four other young patients with the clinical syndrome of patello-femoral pain clinically indistinguishable from the majority were found at operation to exhibit no significant lesion upon the patella.

In reporting this lesion and its association with patello-femoral pain it is important to avoid adding further dubious assumptions to those which already abound in the literature of this subject. Not all cases of patello-

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**Fig. 13**

**Fig. 15**

**Fig. 14**

**Fig. 16**

Figures 13 and 14 show the "blister" lesion on a disc of cartilage approximately 1 centimetre in diameter. Figure 15 is a histological section of fasciculated cartilage showing a defect in the mid zone (on the left) breaking through to the surface (extreme right). (×32.) Figure 16 is the histological section from the edge of the "blister" lesion shown in Figures 13 and 14. Normal cartilage (left) is sharply demarcated from fibrous tissue (right). The heaped up area represents, in cross-section, the wrinkle seen at the edge of the lesion in Figures 13 and 14. (×220.)
femoral pain syndrome can be attributed to it, nor has it been demonstrated whether or not it is sometimes present in the knees of young people who do not complain of pain. Furthermore, the descriptive terminology of cartilage lesions is so imprecise that it has proved impossible to determine the exact nature of the lesion referred to in the surveys quoted earlier whether found at necropsy or at arthroscopy.

With these demurrals it may still be justifiable to suggest that the lesion described as fasciculation could well explain some of the peculiar features of patellofemoral pain syndrome in adolescence. Its situation upon the crest between the odd and medial facets must render it liable to pressure when the knee is flexed to a right angle and beyond. This is the posture at which the joint is usually painful, and it is that part of the patella which on palpation is found to be tender in many cases.

A lesion in the depth of the cartilage in which the tangential surface fibres remain smooth and intact might well persist without progression for many years, and would not occasion abrasive lesions on opposed cartilage, nor initiate a synovial reaction and effusion. In the group of patients referred to above effusion was present in only two—and in both of these the lesion had ruptured (Fig. 17), and the synovial fluid was found to contain innumerable small pieces of shed cartilage which may be thought to have occasioned the effusion by mechanical or chemical irritation of the synovium.

The clinical observation, referred to above, that there is a large number of youthful patients with patellofemoral pain who eventually recover completely, may also be explained if during the period of symptoms the essential fibrous structure of the affected cartilage, in particular the tangential zone of the collagen fibres at the surface, remained intact. There is much evidence to suggest that articular cartilage has little power to regenerate to normal from surface lesions, but it is credible that the lesion epitomised in Figure 4 (Stage 1) might recover without trace.

But how could such a lesion cause pain? Because articular cartilage contains no nerve fibres, and because a smoothly intact articular surface could hardly occasion a local synovial reaction it is supposed that nerve endings in the subjacent bone transmit the painful stimuli. McCall (1969) has demonstrated that under load the non-aligned fibres of the intermediate zone adopt, like a compressed lattice, a more or less tangential alignment, and rebound to their non-aligned state when the load is removed (Fig. 18). A lesion, such as we describe, which disorganises the fibrous structure of the intermediate zone of collagen fibres must render the subjacent bone plate subject to pressure variations from which it is normally defended by the energy-absorbing function of that zone, and may well act as a pain stimulus upon the nerve endings in the subchondral plate.

And lastly, what causes the lesion to develop at this particular site? The contact studies in the foregoing paper suggest that the cartilage on the ridge between the medial and odd facets is subject not only to heavy compression loading but also to the effects of shear as the patella glides off the patellar facets and on to the femoral condyles and back again. The traumatic theory would explain its frequency among the young and athletic and would suggest that the likelihood of its occurring in any particular individual would depend upon minor varia-

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**FIG. 17**
Photograph at operation of a lesion astride the ridge between the odd and medial facets. It is confluent with a second area astride the median ridge. The patient had a large effusion in the knee and the synovial fluid contained innumerable flakes of shed cartilage. Histological examination revealed the lesion to consist of fibrous tissue which had inadequately repaired the large defect from which the cartilage had been shed (see Fig. 21).

**Fig. 18**
Diagram of the effect of loading upon the collagen framework of articular cartilage. It may explain how a lesion in the mid zone disorganises the energy-storing capacity of the material and results in stimulation of nociceptive nerve fibres in the subchondral bone when fasciculated cartilage bears load.
tions in the anatomical shape of the patella. The diagram in Figure 18 would explain the localisation of a traumatic lesion to the mid-zone of the articular cartilage, as has actually been observed. And finally, from our knowledge of the contact areas in full flexion, it might be predicted that the shape of the patella associated with traumatic lesions of the cartilage in the region of the odd facet would predispose also to the development of osteochondritis dissecans on the lateral margin of the medial femoral condyle. A coincidence of this kind occurred in one of our patients. He had severe cartilage changes in his right patella (Fig. 17) and osteochondritis dissecans at the classical site in his left knee (Fig. 19) where the patella appeared at arthrotomy to be normal.

SURGICAL TREATMENT
Since 1966 arthrotomy of the knee has been performed (by J. W. G.) on twenty-seven young patients who complained of persistent patello-femoral pain. The age range in this group was from fourteen to twenty-seven years, and girls predominated over boys in the ratio of 3:2. They had suffered from pain for an average period of two and a half years and had all failed to gain relief from conservative treatment, which included periods of immobilisation in plaster casts and courses of quadriceps exercises. Medial parapatellar arthrotomy was done in these patients.

In four of them no abnormality of the patellar cartilage was found, except for slight surface changes upon the odd facet. The evidence has already been cited for dismissing this finding as a normal characteristic of many patellae, and in these four patients no procedure was carried out and the cause of the patello-femoral pain in them we cannot explain.

In the remaining twenty-three patients the lesion described above as fasciculation was found in one or other of its stages. The area affected was usually about a centimetre in diameter, and treatment consisted in excision of the affected disc of cartilage by making a circumferential incision with a knife and prizing off the cartilage with a small rongue. The subchondral bone was exposed in the floor of the defect thus created, and in the later cases some holes were made through the plate into the cancellous bone. Figure 20 demonstrates the defect which results from excision of the affected area when, as is usual, it is limited to the crest of the ridge between the medial and odd facets. Figure 21 shows the most extensive lesion we have successfully treated in this way, a patella in which there was also present a second centre of degeneration astride the lower part of the median ridge.

The results have been assessed at one year or more in all these cases. Eighteen of the twenty-three patients in whom a lesion was found and excised were relieved of their patello-femoral pain. Five were not improved.

Figure 20—Typical defect resulting from removal of a disc, approximately 1 centimetre in diameter, of fasciculated cartilage from the ridge which separates the medial from the odd facet. Figure 21—Defect resulting from excision of the lesion shown in Figure 17. This patient's knee had remained symptomless and free of effusion when seen three years after operation.
or quickly experienced a relapse, and two of these have since undergone patellectomy. None of the patients in whom the result was satisfactory at one year has experienced a recurrence of symptoms since, and the maximum follow-up period is six years.

**DISCUSSION**

Localised excision of the affected disc of cartilage seems preferable to the practice of shaving. If, as we believe, the deep layers of cartilage are the seat of the primary disorder, the shaving process, creating a saucer-like defect, must unnecessarily remove the important tangential zone of superficial cartilage from healthy surrounding areas. Shaving produces an apparently smoother surface for articulation than does excision of a disc, but actually alters the precisely matched surface contours much more. As the contact prints in the foregoing paper demonstrate, the opposed contours of the patello-femoral joint result in broad bands of contact in all positions from 0 to 90 degrees of flexion, and therefore the creation of a circumscribed cylindrical defect or defects upon the surface need not alter the axes of movement of the patella, though it must increase the force per unit area transmitted through the remaining cartilage. The same principle applies to the treatment of limited areas of osteochondritis dissecans on the femoral condyle, where it is known that excision of the focus is compatible with long continued normal function of the joint.

The case for local chondrectomy being thus made on theoretical grounds, it is reasonable to point to the success of this manoeuvre in eighteen of the twenty-three patients in whom it was practised. However, other conservative surgical treatments have been reported with successful relief of symptoms in a similar proportion of cases. The procedure of shaving the cartilage referred to above has been found successful by many authors (Felländer 1951; Wiles et al. 1956; Wiles, Andrews and Bremer 1960; Cauchois, Lamarque and Rey 1966), though in other series less than half the patients were relieved (Bentley 1970). Outerbridge (1964) reported good results from shaving combined with bevelling off the ridge which limits the superior articular margin of the patellar facets of the femur. Devas and Golski (1973) cured the symptom of patello-femoral pain in seventeen out of twenty young patients by medial transplantation of the patellar tendon. Arthrotomy was not performed in their patients, and so the diagnosis of the cause of the pain was presumptive.

We conclude, from the contradictory nature of this evidence, that it is unwise to rely too heavily upon subjective relief of symptoms in making a case for the aetiological importance of a particular lesion.

**CONCLUSIONS**

In summary, we have been able from naked-eye and histological observations to distinguish two lesions of the articular cartilage of the patella.

A surface degenerative lesion, in no way peculiar to the patella, is found frequently in youth and regularly in maturity, particularly upon the patella's odd facet. Its presence cannot be held responsible for the symptom of patello-femoral pain in young people.

A basal disorder of cartilage, called fasciculation, has been detected upon a specific part of the patella of young patients suffering from intractable patello-femoral pain, and arguments are adduced to suggest that it is a cause of that pain.

A series of patients has been treated by excision of a disc of fasciculated cartilage with relief of pain in most cases.

**REFERENCES**


