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KINEMATIC ASPECTS OF THE HUMAN KNEE-JOINT

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The close functional relation between the geometry of the articular surfaces of the knee and the fibre arrangement of the cruciate ligaments is illustrated with a series of two- and three-dimensional kinematic models. Incongruity of the articular surfaces *per se* is not conclusive proof of the existence of a polycentric movement, nor is it possible to deduce the characteristics of such a movement from the non-circular profiles of these articular surfaces only. The models show that a given set of insertion points for ligament fibres can be combined with two different types of fibre arrangement: crossing or uncrossing fibres, and with an infinite number of articular profile combinations: concave, plane or convex. These combinations form a continuous range and each has its own kinematic characteristics, e.g. different combinations of gliding and rolling components of their movements, different velocity characteristics, different paths for the shift of the contact areas, and different paths of the rotation axes. Changing the insertion points of ligaments leads to a change in kinematic behaviour which must be more or less in conflict with the given geometry of the articular surfaces, while on the other hand replacement by articular surfaces with a different geometry must result in possibly damaging strain on the original ligaments.

MEASUREMENT OF THE DRAWER SIGN OF THE KNEE IN PATIENTS

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A method was developed for continuous measurement and registration (as a load curve) of both the force

applied and the drawer sign in patients during a drawer test. The drawer test is performed in two flexion positions: 25° and 90°. The upper leg is fixed (not rigidly) in a clamp. The foot is fixed to suppress endo- and exorotation movements. The force is applied manually and electronically measured via a measuring cell. Force is applied in both anterior and posterior direction in steps from about 20 Newton to 250 Newton (if tolerated). At each force value, the displacement of the upper and the lower leg is registered electronically via superficial boneparts (patella and tuberosity respectively). The displacement signals are subtracted from each other by an on-line micro-computer. The outcome, together with the force magnitude, is shown in a curve on the screen. A *printout* of this curve is added to the case record. The method is now being tested for reliability. Possible applications include:

- comparison of the drawer sign before and after treatment,
- measurement of the physiological drawer sign,
- the incidence of abnormal drawer sign in at-risk groups.

The method is rarely experienced as unpleasant by the patients, and the 25° measurement can be performed in an acute stage.

RESULTS OF ARTHROSCOPY IN TRAUMATIC HAEMARTHROSIS OF THE KNEE-JOINT

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A prospective study was performed to establish the diagnostic value of arthroscopy in traumatic haemarthrosis of the knee-joint. In 107 consecutive patients with a trauma of the knee-joint intra-articular blood was found at *clinical examination*, while no abnormality was seen on routine radiographs. All these patients underwent arthroscopy under general anaesthesia. This

was done within 24 hours of admission in 84 per cent of cases. The knee injury had been caused by an accident during sports activities in two-thirds of the cases, football being responsible for more than 50 per cent.

Arthroscopy was immediately followed by arthrotomy in 69 of the 107 patients. Only one complication was observed: staphylococcal arthritis after arthrotomy. All possible combinations of intra-articular lesions were found; 76 anterior cruciate ligament ruptures were observed, including 51 fresh total ruptures. Significant findings were:

- isolated anterior cruciate ligament ruptures in 22 patients, and six isolated major (osteo)chondral fractures (the latter without any radiographic evidence);
- of 18 knee-joints which appear to be stable at clinical examination, eight proved to be unstable under general anaesthesia. Five of the remaining 10 knee-joints had an isolated total rupture of the anterior cruciate ligament, while the other five showed an osteochondral lesion;
- of 55 knee-joints found to be unstable at clinical examination, six showed old ligament ruptures, and consequently arthrotomy could be avoided.

The findings warrant the conclusion that, in traumatic haemarthrosis of the knee-joint, an exact diagnosis can only be made by arthroscopy. The authors therefore recommend arthroscopy in all cases of traumatic haemarthrosis of the knee-joint without radiographic evidence of a lesion.

THE COURSE OF HEALING OF TENDONS AND LIGAMENTS

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The anterior cruciate ligament is surrounded by a synovial fold in which the nutrient vessels take a longitudinal course. These vessels anastomose with vessels in the infrapatellar fat, with periosteal and with intra-ligamentary vessels. Only in the intercondylar notch are a few anastomoses between intraligamentary and endosteal vessels found. Vascular density is minimal at the centre of the ligament.

Every injury entails structural damage, varying from hyperextension to total rupture. Hyperextension (micro-rupture) causes a small haematoma at the site of the lesion, and local necrosis ensues. After 2 weeks there is ingrowth of new vessels and fibroblasts start to form collagen which, during the phase of maturation from 9-12 months, orients itself to the tensile forces exerted. After this type of injury the cruciate ligament never resumes its original length. The spontaneous healing process after a partial lesion takes an identical course, but it is only at the base that the resulting defect

is more or less filled (O'Donoghue 1966, Arnoczky 1977). In personal experiments on beagles in which a defect was produced over half the width of the cruciate ligament halfway its length, however, complete filling of the defect was observed in two out of nine animals. During the phase of maturation the newly formed collagen oriented itself to the tensile forces exerted.

Immobilization in a plaster cast exerts no influence on the course of spontaneous healing but does weaken other ligamentary structures. After total rupture, continuity can be restored only by adaptation, with or without an augmenting graft.

Other factors than the above-mentioned also determine the course of healing. They include: vascularization kept intact from the infrapatellar fat and the synovia (Arnoczky 1979), the fixation, the tension on the sutured ligament, and the orientation of the graft (if used).

RECONSTRUCTION OF THE ANTERIOR CRUCIATE LIGAMENT; AN EXPERIMENTAL STUDY OF LENGTH CHANGES IN VARIOUS TYPES OF RECONSTRUCTION

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An anatomical model was developed to test various intra-articular anterior cruciate ligament reconstructions. Twelve different reconstructions were tested in an identical way in each of four cadaver knee specimens.

The results indicate that "over-the-top" reconstruction of the anterior cruciate ligament is an unfavourable method in mechanical terms. This type of reconstruction is likely to give rise to excessive laxity and insufficiency of the reconstructed tissues.

During normal knee motion from 0° to 130° flexion, least laxity is observed in a graft guided through the lateral femoral condyle via a posterior tunnel. The position of the tibial tunnel is less essential, but a tunnel localized as far anteriorly as possible is the most desirable.

When the tunnels are drilled correctly, it is advisable to fix the ligament reconstruction with the knee in 45° flexion, with initial postoperative immobilization in 45° flexion.

A MULTI-CENTRE FOLLOW-UP STUDY OF THE RESULTS OF OPERATIVE THERAPY OF LESIONS OF THE KNEE LIGAMENTS

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At the request of the scientific committee of the

Netherlands Orthopaedic Society, nine investigators performed a follow-up on the results of knee ligament operations. The study comprised 648 (285 acute and 363 chronic) patients in 12 orthopaedic departments, who fulfilled the following criteria:

- operation and postoperative management clearly defined;
- no intra-articular fractures other than avulsion fractures;
- minimal follow-up period 1 year.

In this retrospective study it proved impossible to classify all patients by diagnosis because no entirely reliable inventory of all ligamentary and capsular lesions was available. For this reason the results were determined per therapy group. Each therapy group was divided into acute and chronic cases. Three types of results were distinguished per therapy group:

1. Overall anamnetic results: satisfied - dissatisfied;
2. Specific anamnetic results: patient's assessment of knee function;
3. Results of physical examination.

re 1. The question whether results were regarded as satisfactory was answered by the patient in the waiting-room, in writing and anonymously (85% of the acute and 68% of the chronic patients were satisfied).

re 2. Lysholm's knee-scoring table (Thesis 1981) was used, with a minor modification. In this table the patient could score 25-0 points for stability, 25-0 points for presence or absence of pain, and 35-0 points for answers to questions about limping, use of a support, walking up and down stairs and squatting. The maximum possible score was 85 points. At least 84 points had to be scored for the classification "good". The result was classified as "poor" when there was frequent pain (less than 5 points) or frequent instability (less than 5 points), or when functions were poor. All patients between "good" and "poor" were classified as "moderate".

In chronic patients the preoperative Lysholm score was compared with that for the ultimate situation.

re 3. The investigators were given special training in uniform interpretation of physical findings. Each patient was examined by two independently working investigators. In this respect, also, criteria for good, moderate and poor results were established. In the stability study the result could be classified as "good" despite a "+" score for two aspects. A "+ +" score for one aspect led to a "poor" classification. The classifications "good", "moderate" and "poor" for the anamnetic and physical findings were used uniformly for all study groups in the following abstracts.

Some remarks:

Imperfections of this study: A brief follow-up (less than 3 years for 50% of the patients) and inadequate

documentation on diagnosis, so that no diagnostic groups could be studied.

Positive points: Objective factor in physical examination as a result of uniform training of investigators, objective factor in anamnetic studies (scoring table), a large number of patients and a large data bank which comprised far more data than indicated in the following abstracts.

LESIONS OF THE MEDIAL LIGAMENTARY AND CAPSULAR APPARATUS

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A study was made of 145 patients in whom the medial ligamentary and capsular apparatus of the knee was repaired (81 acute and 64 chronic cases).

In the acute group, usually treated by suture of ruptured structures, physical examination revealed a good result in 75 per cent; anamnetically, the result was good in 50 per cent. The favourable results were observed after operations performed between the 3rd and the 7th day after the injury. More than 50 per cent of the patients in this group had resumed intensive sports activities after the operation.

Chronic knee instabilities were usually treated by means of a graft, as a rule of the Slocum type. Physical examination revealed a good result in only 13 of the 64 patients; anamnetically, the result was good in only six patients.

In the entire group, no distinct improvement occurred after suture of the posterior oblique ligament. Untreated accompanying ligamentary lesions (so far as diagnosed) did not always influence the result unfavourably. Results in knees submitted to meniscectomy as well were less good than those in knees with intact menisci.

RESULTS OF AND NOTES ON FRESH ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTIONS

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A study was made of the results obtained in 36 patients treated solely by anterior cruciate ligament reconstruction, regardless of possible other lesions. The follow-up period was 3½ years.

Objective results were good in 37 per cent, moderate in 40 per cent and poor in 23 per cent. Subjective satisfaction was expressed by 73 per cent of the patients. The poor result in seven of the ten cases was caused by restriction of flexion ranging from 20° to 60°; these pa-

tients had all been immobilized longer than 14 weeks. The remaining three patients complained of pain.

A positive pivot shift existed in 10 patients, eight of whom never complained of insufficiency and were subjectively satisfied. This is in agreement with the results of all acute operations for fresh knee ligament lesions (N = 285).

The findings warrant the conclusion that a postoperative positive pivot shift test does not influence the result unfavourably. In all anterior cruciate ligament reconstructions (N = 138), the stability of the reconstructed ligament was tested with the aid of the Lachman manoeuvre.

Reinsertions of proximally localized intraligamentary ruptures had a significantly better result than reinsertions of ruptures in the middle or distal one-third of the anterior cruciate ligament. This result corresponds with that of graft reconstructions of the anterior cruciate ligament. Consequently, it seems sensible to reinsert all proximally localized ruptures and to treat all other cases by graft reconstruction of the anterior cruciate ligament.

ACUTE ANTERIOR CRUCIATE AND MEDIAL LIGAMENT LESIONS

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A follow-up study was performed of 88 patients with anterior cruciate and medial ligament lesions. In all cases the lesion of the medial structures had been sutured. In 74 patients the anterior cruciate ligament had been sutured (group A), whereas in 14 patients this had not been done (group B). A partial anterior cruciate ligament rupture had been present in five cases in group A and seven cases in group B; a distal bone avulsion had occurred in six cases in group A and in two cases in group B. In three patients of group A a primary extra-articular reconstruction was performed in addition (Slocum procedure in two cases and Ellison procedure in one case); in group B two patients were thus treated (Slocum procedure in both).

The percentages of good, moderate and poor Lysholm scores in the two groups did not differ significantly. Findings at physical examination were better in group B, particularly as a result of the good scores in partial anterior cruciate ligament lesions. The total anterior cruciate ligament ruptures left unsutured scored less well at physical examination, but anamnestically (Lysholm score) equalled the group with sutured anterior cruciate ligament ruptures (group A). The interval between accident and operation (0-2, 3-7 or 8-14 days) did not distinctly influence the Lysholm score, but results at physical examination were best in the group operated on 3-7 days after the injury.

INTRA-ARTICULAR ANTERIOR CRUCIATE LIGAMENT RECONSTRUCTION AS AN ISOLATED PROCEDURE IN CHRONIC KNEE LIGAMENT PROBLEMS

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This follow-up study revealed that 70 per cent of chronic knee ligament problems involved anterior cruciate ligament insufficiency. Regardless of the ultimate diagnosis, 20 per cent of these "chronic anterior instability" problems were treated by intra-articular anterior cruciate ligament reconstruction without accompanying peripheral reconstruction. In most cases a static intra-articular anterior cruciate ligament reconstruction was performed with the aid of a pedicled patellar tendon flap.

The follow-up on this group of 52 patients averaged a period of 3 years. The preoperative situation in this group was highly favourable with high Lysholm scores and a history of previous surgery in only a few cases.

At physical examination 15 per cent of patients no longer showed any demonstrable instability. The remaining patients showed a positive drawer test (70 per cent), a positive Lachman test (60 per cent) and a distinct positive pivot shift (60 per cent) as well as instability at other levels, notably medial and/or lateral instability.

The patients themselves were only moderately satisfied with the improvement in stability and also complained of (increased) pain in the joint treated. Despite the favourable preoperative situation in these cases, intra-articular anterior cruciate ligament reconstruction as an isolated procedure produced only moderate subjective and objective results.

EXTRA-ARTICULAR ANTERIOR CRUCIATE LIGAMENT-SUPPORTING RECONSTRUCTION IN CHRONIC INSUFFICIENCY

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Thirty-eight patients were treated by pes anserinus displacement according to Slocum. Preoperative examination revealed gross instability in 65 per cent. There were no postoperative complications. Results were relatively favourable in terms of ambulation time, unfitness to work for more than 12 months and number of patients permanently unfit to work. Sports achievements were below average. A striking finding was the pronounced improvement of the pain score.

Physical examination revealed that the group was far below average, but in view of the dynamic element of this operation this is not surprising. Not a single knee

was stable, and a pivot shift test was positive in 65 per cent. Nevertheless, 70 per cent of the patients were satisfied with the result.

Forty-three patients were treated by lateral tract reconstruction. Preoperative examination revealed gross instability in 75 per cent and a positive pivot shift (2+) in 55 per cent. Serious postoperative complications developed in three cases. Ambulation generally gave no difficulty. Possibilities to resume sports were reasonable.

At the follow-up of the Lemaire/MacIntosh group, 45 per cent still had a positive pivot shift (2+ in two patients). The very marked improvement in stability after the Hughston procedure was conspicuous. Physical examination revealed a positive pivot shift in 35 per cent (2+ in none); 76 per cent of the patients were satisfied with the result of the operation.

XENOGRAFTS

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A nation-wide follow-up study provided data on 39 patients in whom chronic ligamentary insufficiency was repaired by xenograft reconstruction. Xenografts were used in isolated anterior cruciate ligament reconstruction in 13, in isolated posterior cruciate ligament reconstruction in 8, and in combined peripheral and/or cruciate ligament reconstruction in 18 patients. For the isolated cruciate ligament reconstructions a control group was formed of patients matched as to follow-up period, type of operation and preoperative complaints. No significant differences were found between the xenograft group and the control group.

Subjective results: 65 per cent of patients were satisfied; alleviation of pain was hardly achieved but instability symptoms were markedly reduced.

Functional Lysholm score: good in 10, moderate in 55 and poor in 35 per cent.

Objective results: good in 20, moderate in 30 and poor in 50 per cent.

The discrepancy between the subjective (65 per cent satisfied) and the objective results (good in only 20 per cent) remained unexplained. Some degree of correlation with a positive pivot shift was found, but there was no correlation with the Lachman test or the anterior drawer test. There were three major and four minor complications in the xenograft group, and no complications in the control group. The follow-up period was 15 months.

Apart from the complications, the results of xenograft reconstructions after a follow-up of 15 months are the same as the results of Jones and semitendinous reconstructions.

The combined peripheral and cruciate ligament xenograft reconstructions are not less successful than the isolated reconstructions.

LATE RESULTS OF OPERATIONS FOR FRESH KNEE LIGAMENT LESIONS

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Of 39 patients with fresh ligament lesions treated by operation between 1972 and 1975, 27 presented for a follow-up examination. The average age was 28 years; 21 were males and six were females. A sports injury had been the cause of the knee ligament lesion in 18 cases, and a road traffic accident in seven. None of the patients had had knee symptoms prior to the accident. Examination took place under general anaesthesia; stress X-rays were made and the knee was inspected at the operation. All ruptured tissues were sutured, and if necessary a tunnel was drilled to reinsert a cruciate ligament. Ruptured menisci were sutured so far as possible. All sutures were knotted continuously after repositioning the knee as carefully as possible. In some cases the collateral ligaments were fixed with the aid of a Blount staple. Post-operative treatment consisted of immobilization in a plaster cast for 2-6 weeks. In two instances a knee was mobilized under general anaesthesia.

The Lysholm score was: good in 56 per cent and moderate in 44 per cent. Results of physical examination: good in 33 per cent, moderate in 48 per cent and poor in 19 per cent. Osteoarthritis was found on the medial side of the knee in 39 per cent, on the lateral side in 28 per cent and in the patellofemoral region in 50 per cent. The severity of osteoarthritis was stage 1 in 79 per cent, stage 2 in 11 per cent and stage 3 in 11 per cent.

LONG-TERM RESULTS OF CONSERVATIVE MANAGEMENT OF FRESH KNEE LIGAMENT RUPTURES

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Of 156 patients treated for fresh ruptures of one or more knee ligaments by plaster cast or functional therapy, 56 could be followed up (mean follow-up period 8.1 years). Hughston's criteria were applied.

There was no correlation between objective and subjective results; only eight patients (14 per cent) scored poorly on at least one of the criteria. Of 39 active sportsmen, six could not resume their sports activities. Three of the 56 patients had to change their jobs.

The principal finding was that no correlation was demonstrable between knee instability of long standing and gonarthrosis. However, a significant correlation was found between gonarthrosis and meniscectomy.

RESULTS OF A FOLLOW-UP OF 51 PATIENTS WITH AN ANTERIOR CRUCIATE LIGAMENT RUPTURE

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Seventy patients with an arthroscopically confirmed old anterior cruciate ligament rupture were examined after a follow-up period of at least a year. Additional intra-articular lesions had been treated during the arthroscopic examination. Nineteen patients had been treated secondarily by anterior cruciate ligament reconstruction, and were therefore eliminated.

An inquiry was made among the remaining 51 patients in order to establish the extent to which the arthroscopy had influenced the complaints and the extent to which former sports activities had been resumed. The patients were divided into subgroups according to the nature of the arthroscopic intervention: 1) solely diagnostic (9), 2) with closed partial medial meniscectomy (15), 3) with closed partial lateral meniscectomy (10), 4) with resection of the anterior cruciate ligament stump (8) and 5) with both medial and lateral closed partial meniscectomy (8).

Eleven patients (21 per cent) had no complaints, and 24 patients (47 per cent) reported diminished complaints. Twenty-two patients (43 per cent) had resumed their former sports activities.

OPERATIONS FOR CHRONIC POSTERIOR CRUCIATE LIGAMENT INSUFFICIENCY

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Posterior cruciate ligament reconstructions were performed in 32 patients, divided into two subgroups: 16 patients with posterior cruciate ligament reconstruction only, and 16 with posterior cruciate ligament reconstruction and capsular sutures and (if necessary) advancement.

The two groups did not significantly differ in Lysholm score: 15% good and 40% poor (this is significantly less good than in the acute patients; see the next abstract). Both groups showed an unmistakably better Lysholm score than before the operation.

Physical examination always revealed a posterior drawer (whereas in 20% of the acute patients no posterior drawer was found). The two groups did not significantly differ in findings at physical examination: 20% good and 55% poor (this is significantly less good than in the acute patients).

No correlation was found between the results and a meniscectomy, nor between the results and the duration of the follow-up period.

Conclusions:

1. The findings warrant no conclusion about the therapy of choice.
2. A posterior drawer persisted in all patients.
3. The results in the chronic patients are significantly less good than those in acute patients.
4. On average, the operation led to unmistakable functional improvement.

INCIDENCE OF CHRONIC KNEE LIGAMENT INSUFFICIENCIES IN PROFESSIONAL FOOTBALL PLAYERS

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A study was made of 202 professional football players; 58 were eliminated in view of recent injuries, recent operations, knee ligament reconstructions or bilateral knee ligament insufficiencies. The Hughston protocol was used. The qualification had to be at least +.

Of the 144 men (average age 28 years, average period of active professional football 7 years), 50 (34 per cent) had a knee ligament insufficiency in comparison with the contralateral knee: anteromedial in 24, anterolateral in 5, anteromedial and anterolateral in 6, medial ligament in 9, lateral ligament in 4 and anterior cruciate ligament in 2 cases.

Meniscectomy had been performed as often on the intact as on the abnormal knee. The insufficiency involved the standing leg in 35 cases (18 of the anteromedial and all anterolateral lesions) and the kicking leg in 15 cases (including 6 of the anteromedial lesions).

In all persons examined the condition of the quadriceps muscle (and particularly that of the vastus medialis) was optimal. All were playing first division football without complaints.

Conclusion: Not all knee ligament lesions require an operation, because well-trained musculature can compensate an insufficiency. An indication for operation can be determined only when the musculature of the upper leg is in optimal condition.

COMBINED INTRA- AND EXTRA-ARTICULAR RECONSTRUCTIONS FOR CHRONIC ANTERIOR CRUCIATE LIGAMENT INSUFFICIENCIES

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A group of 71 patients was divided into three therapy groups:

- I. intra-articular + lateral reconstruction (n = 38)
- II. intra-articular + medial reconstruction (n = 21)

III. intra-articular + lateral + medial reconstruction (n = 12).

The indication for therapy can be deduced from the preoperative documentation. A positive anterior drawer and positive pivot shift were predominant in Group I. Group II was characterized by a positive anterior drawer which increased at exorotation of the distal leg. Group III showed an anterior drawer which increased in exorotation and a positive pivot shift.

Postoperative treatment was non-functional in all cases. As compared with the totality the follow-up was shorter, more complications developed and postoperative inability to work was more often prolonged. The possibility of taking part in sports improved distinctly. Sports involving rotatory movements improved markedly in Group I. All groups showed subjectively improved stability and an improved Lysholm score. The pivot shift improved in Group I, but in Groups II and III improvement was below average. Serious loss of function occurred more often. Some 85% of the patients were satisfied with the result.

An analysis of the poor results reveals that poor subjective results are caused primarily by pain, and to a lesser degree by residual instability. The poor objective results are characterized by persistence of an anterior drawer, followed by loss of function.

REPAIR OF ANTERIOR INSTABILITY OF THE KNEE-JOINT WITH THE AID OF A GRAFT FROM THE PATELLAR LIGAMENT AND THE FASCIA LATA

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The authors describe a technique by which anterior instability of the knee-joint can be adequately treated. It involves repair of the anterior cruciate ligament with the aid of a graft from the patellar ligament, in combination with femorotibial tenodesis using tissue from the fascia lata. The repair of the anterior cruciate ligament restores the central pillar of the knee-joint, while the tenodesis controls the rotatory component.

A long strip of fascia lata, left attached to Gerdy's tubercle, is passed behind the collateral/lateral ligament through a bony tunnel in the lateral condyle and passed back beneath the ligament to Gerdy's tubercle.

A free graft is taken from the patellar ligament and bone fragments are taken from the patella and the tibial tuberosity. The bone fragments are armed with a metal wire to produce tensile strength. The patellar fragment is buried in a depression in the posterosuperior part of the lateral condyle, and fixation to a supracondylar AO-screw is effected via a drill tract in the lateral condyle. The fragment from the tibial tuberosity is pushed into a tunnel in the tibial head. This oblique, nearly vertical tunnel starts slightly medial to the original attachment of the anterior cruciate ligament to the tibial

plateau and extends in anterior direction. The tension of the graft can be controlled by means of an AO-screw (adjusting screw), introduced into the tibial shaft in an oblique distal direction.

This exercise-stable repair of anterior instability of the knee-joint permits functional after-treatment. Flexion exercises are started immediately after operation so that 90° knee flexion is achieved 10 days later. The entire exercise programme is designed to achieve maximal function and optimal stability.

This technique was used to treat a group of 35 patients; the follow-up on this group now amounts to 18 months.

BIOMECHANICAL ASPECTS OF THE KNEE-JOINT LIGAMENTS

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The function of the ligaments in knee-joint freedom of motion is intimately related to their complex spatial geometry and their non-linear mechanical properties. Recent biomechanical *in vitro* analyses of knee-joint kinematics and ligament length patterns, using accurate (three-dimensional) roentgen stereophotogrammetry, have shown quantitatively how different parts of the ligaments play alternative roles throughout various flexion and exo-endorotation positions (R. van Dijk, Thesis 1983, University of Nijmegen). The influences of different ligament parts in clinical "stability" tests can be evaluated on the basis of this information and data from the literature on mechanical properties of the ligaments.

This paper reviews the available knowledge on biomechanical aspects of the knee-joint ligaments and discusses by way of example the role of the anterior cruciate ligament in the anterior drawer test, evaluated as mentioned above.

The results indicate that more precise clinical assessment of the nature and extent of knee ligament injuries is feasible if both the forces and the displacements are objectively measured during the test.

COMPUTER KNEES

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Publications of research results regarding the pattern of knee motion and the influence of the ligaments on this pattern are equivocal. The wide variation in reported results is caused by differences between the knees studied and insufficient knowledge of the forces applied to the knees. This is why in 1978 the Eindhoven Uni-

versity of Technology started the development of a computer simulation model. Such a model consists of a mathematical description of a human knee-joint. The input required includes the geometry of the knee and the properties of the various materials of which the knee consists.

For determination of the geometry, a set-up was designed in which accurate three-dimensional measurement of the knee is possible. With regard to the properties of the materials, various studies of the literature were used.

In the computer model the direction and magnitude of forces applied to the tibia and the femur can be programmed. The effect of these forces on freedom of movement, ligaments and cartilage can be calculated. Addition or omission of knee parts is no problem in such a model.

The model so far designed has already provided some valuable information. Insufficient knowledge of the properties of ligaments and cartilage constitutes the greatest barrier to further development.

LIGAMENTARY AND MENISCAL LESIONS ASSOCIATED WITH FRACTURES OF THE TIBIAL PLATEAU

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Between 1961 and 1981, 123 fractures of the tibial plateau were treated by operation. Twelve ligamentary lesions and 34 meniscal lesions were found in 40 patients. Ligamentary lesions were found mainly in association with marginal avulsion fractures of the lateral and medial plateau, while meniscal lesions mainly occurred in association with avulsion fractures with impression of the plateau.

In all cases efforts were made at surgical repair of the ligament; the injured or displaced meniscus was left *in situ* after repair.

A comparative follow-up study of differences in results between the group with and that without ligamentary and/or meniscal lesions was not performed.

ACUTE LESIONS OF THE POSTERIOR CRUCIATE LIGAMENT

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In a nation-wide follow-up study, 55 patients with posterior cruciate ligament lesions repaired by acute surgery were examined and evaluated. The most common causes of the lesions had been traffic injuries, followed by sports injuries. Some 75 per cent of the patients had

undergone surgery within a week. Minor complications had developed in two cases. The follow-up period averaged almost 4 years. The patients were divided into three groups:

Group I: 11 patients treated solely by suture of the posterior cruciate ligament.

Group II: 8 patients treated by re-insertion of an avulsion fracture of the posterior cruciate ligament and suture of a capsular rupture.

Group III: 33 patients treated by suture of the posterior cruciate ligament and of a ruptured capsule. In 13 of these patients the anterior cruciate ligament had been sutured as well (primary reconstruction in three of them).

The results in the three groups were similar.

Subjective results: Satisfactory in 86 per cent; the knee never gave way in 75 per cent; and 50 per cent never experienced pain.

Functional Lysholm score: Good in 40, moderate in 50 and poor in 10 per cent.

Objective results: Good in 40, moderate in 20 and poor in 40 per cent.

The posterior drawer test was positive in 43 and negative in 12 patients. No correlation was found between a positive posterior drawer and the ultimate subjective result. The posterolateral drawer test showed the same discrepancy between objective and subjective results.

The prognosis of primarily repaired posterior cruciate ligament lesions is good after 4 years. When all ruptured structures are repaired, the results in combined posterior cruciate ligament lesions are as good as those in avulsions of the posterior cruciate ligament. The discrepancy between the objective and the subjective results remained unexplained.

FUNCTIONAL POSTOPERATIVE TREATMENT OF CRUCIATE LIGAMENT RECONSTRUCTIONS

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Thirty-two patients with an intra-articular cruciate ligament reconstruction (modified Kenneth-Jones combined with iliotibial tract reconstruction according to Lemaire) were given functional postoperative treatment. Ice packs were applied after the operation.

The suprapatellar bursa and the patella were mobilized daily from the second day after operation, while the knee was moved passively from full extension to about 90° flexion under the guidance of a physiotherapist. Ten days after the operation the patient was allowed to walk without bearing weight, with a removable posterior splint. Daily physiotherapy was provided after discharge from hospital. The splint was removed after 6 weeks, but weight-bearing was still avoided. Weight-bearing was started after 8 weeks and gradually increased.

Full weight-bearing was resumed after the 10th week, when muscular strength and coordination were sufficient. All patients were given after-treatment at the same institute, where a number of parameters were registered.

Virtually all patients showed good mobility 16 weeks after the operation. Most patients showed a positive Lachmann test and a positive drawer sign as patellar mobility and function increased. A positive pivot test could be elicited in one patient. One female patient developed arthritis 3 weeks after the operation and had

to submit to arthrolysis 12 weeks after the operation. Two other patients had to undergo forced flexion under general anaesthesia 12 weeks after the operation. One patient developed an avulsion fracture of the lower pole of the patella after 24 weeks. Persistent painful restriction of extension in one female patient was abolished after arthrotomy.

Virtually all patients showed adequate function (average restriction of extension 5° and flexion up to 130°) after 5 months.