A BIOMECHANICAL STUDY OF LATERAL RELEASE AND ELMSLIE-TRILLAT PROCEDURES TO RESTABILISE THE MALTRACKING PATELLA

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Abstract - ***The resistance of patella against lateral displacement (i.e. the stability), was studied under a range of conditions in vitro, at a range of knee flexion angles. Muscle forces were applied in physiological directions along the separate quadriceps muscles. Normal muscle actions with constant tension showed constant patellar stability up to sixty degrees knee flexion, and then a significant increase at ninety degrees. A pathological knee was simulated by relaxing vastus medialis, and lateral stability then dropped by 47%. Isolated retinacular release in the pathological knee did not improve stability significantly towards normal, while 6mm tibial tubercle medialisation restored stability by 52% towards normal, except neat full extension. Combined release plus tubercle medialisation restored stability 59% towards normal in knee flexion, and 23% up to ten degrees flexion.***

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INTRODUCTION

Fulkerson and Hungerford (1) in 1959 reported 137 different surgical techniques for treating patellofemoral stability disorders, such as lateral patellar compression syndrome or recurrent subluxation or dislocation. Of these, lateral retinacular release and tibial tubercle medialisation are among the most popular. Unfortunately these reports lack objective data and the way they work.

Lateral retinacular release (LRR), in which lateral soft tissue attachments are transected from the patella, has been recommended for treating a contracted lateral retinacular (2), subluxation or tilt (1) or recurrent dislocation (3). Biomechanical studies (4-6) have found no significant changes in tracking or contact pressures, but these can be criticized for having performed the LRR procedure on cadaver knees with normal loads applied.

Tibial tubercle medialisation (TTM) acts to reduce the Q angle, and the Elmslie - Trillat technique, in which the distal end of a long bone block is kept attached to the tibia while the proximal end is swung medially, has been recommended in patellar subluxation and dislocation disorders (1,7,8). We found only one biomechanical study of TTM (9), which did not simulate pathological conditions and found no consistent effect.

We did not find any published study of lateral patellar stability across a range of knee flexion angles, but medial soft tissue restraints have been studied at full extension (10).

The objectives of this biomechanical study were : to quantify lateral patellar stability across a range of knee flexion angles, to simulate a pathological knee with dysfunctional vastus medialis, and quantify the resulting loss of stability, and to evaluate the effectiveness of LRR and TTM procedures in restoring patellofemoral joint stability towards normal.

MATERIALS AND METHODS

Six fresh-frozen cadaver knees, aged 27 to 86 years with no evidence of surgery or disease, were used. The skin, fat, iliotibial tract and muscles other than the quadriceps were removed. The vastus medialis (VM) and vastus lateralis (VL) were separated from the central rectus femoris (RF) and vastus intermedius (VI) proximally, preserving their distal merging and the retinaculae. Cloth strips were sewn into the three muscle groups, to provide muscle loading attachments. The specimens included 20 cm of femur and 15 cm of tibia plus fibula. An intramedullary mounting rod was cemented into the femur, and a steel cap attached to the superficial surface of the patella, to allow displacing forces to be applied. The specimens were wrapped in wet towels to prevent dehydration.

We chose a new approach to describe patellar stability, based on the classic mechanical definition: the patellar restraining force being the force required to displace the patella from its stable position. This allows for quantification of stability.

In order to displace the patella laterally in a controlled manner while measuring the force required, the knee was mounted in an instron 1122 material testing machine. It was secured via the femoral intramedullary rod with the lateral aspect uppermost, and with the tibia fiexed in a horizontal plane (Fig. 1).

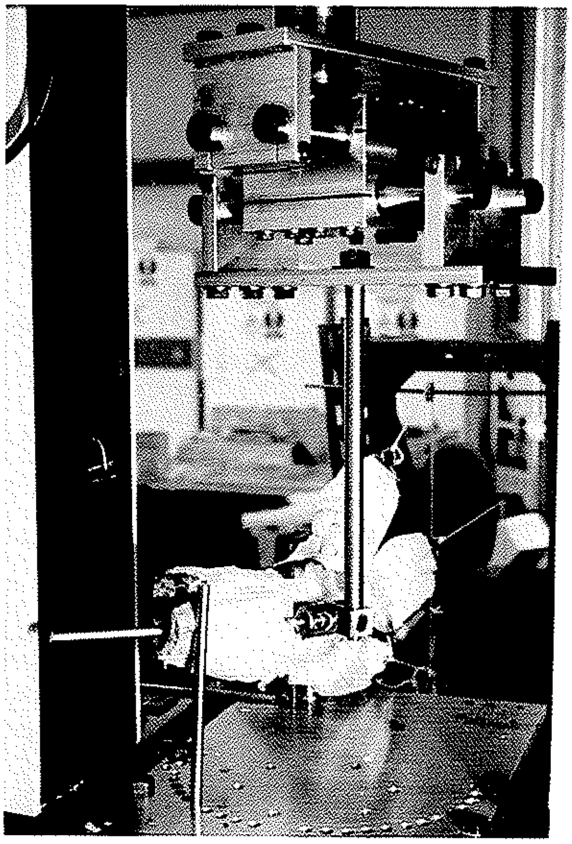

Fig. 1- The cadaver specimens were mounted in an instron testing machine with the lateral aspect uppermost, the femur fixed and the tibia flexed in horizontal plane.

The three muscle groups were loaded via cables passed over pulleys to hanging weights, that acted in physiological directions: VL 20 °lateral and 0 °anterior; RF+ VI 0 °lateral and 5 °anterior; VM 35 °medial and 0 °anterior (11,12). A total quadriceps tension of 175N was distributed according to the physiological cross-sectional areas of the muscles; VL 35%, RF + VI 40%, VM 25% (12), when simulating normal actions. Extension of the knee was blocked, at each angle being studied, by means of a transverse rod anterior to the distal end of the tibia. This arrangement did not constrain secondary motions of the tibia.

The patella was connected to a load cell on the moving crosshead of the instron. At the load cell, a three degree-of-freedom mounting allowed for patellar anterior-posterior and proximal-distal migration, plus flexion-extension rotations. At the patella, a two degree-of-freedom joint allowed for patellar tilt and rotation; this was locked on to the patellar cap with the patella in its normal position at 45 °knee flexion (Fig. 1). This complex attachment allowed the patella to move as the knee flexed; it also allowed the patella to climb out of the groove as it was displaced laterally.

Patellar stability was tested with the normal muscle tensions at 0, 10, 20, 30, 45, 60 and 90 degrees knee flexion. The patella was displaced 10 mm laterally from its stable position at 100 mm/min. Previous work (10) had shown that 12.7 mm displacements did not damage the tissues, so 10 mm displacement cycles gave reproducible force-displacement curves. The third load cycle was recorded at each knee flexion angle, using LAB Windows (National Instruments Co.) software on a PC.

To simulate a pathological knee, the VM was relaxed and its tension was shared between the other muscles. The lateral stability tests were repeated.

In order to find how surgical procedures would restore stability towards the normal state, LRR and TTM procedures were performed, and the resulting patellar stability was measured while still influenced by the pathological (VM relaxed) muscle loads. The retinacular release was extended distally to transect the patellotibial band and proximally to include the distal vastus lateralis obliqus (VLO) fibres (Fig. 2). The Elmslie Trillat TTM procedure created a tongue of bone 50 mm long and 5 mm thick, that was left attached distally. The proximal end was swung 6 mm medially and secured with a bone screw (Fig. 3). Patellar stability was measured across the range of knee flexion angles:

(1) after LRR alone;
(2) after combining TTM with the LRR;
(3) after suturing the LRR to leave a TTM alone.

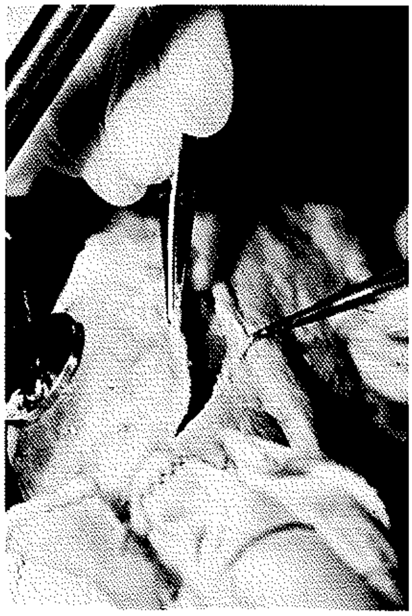

Fig. 2- The lateral retinaculum was released in the cadaver specimens.

RESULTS

The general pattern of the curves was very similar between specimens, although the force needed to produce a given displacement varied. There was no significant change in the force needed to produce a 5 mm lateral patellar displacement between 0 ° and 60 ° knee flexion (P=0.621 by ANOVA), but increased significantly between 60 ° and 90 ° (P< 0.05). This was mainly due to the greater initial resistance to displacement at 90 °.

Relaxation of the VM caused the force needed for 5mm of patellar displacement drop by 47 ± 9% (P< 0.05). Figure 4 shows that the patella was least stable at 30 ° knee flexion - significantly less stable than in full extension (P=0.048).

The LRR procedure did not increase patellar stability significantly (P>0.686) over the pathological VM relaxed state (Fig. 4).

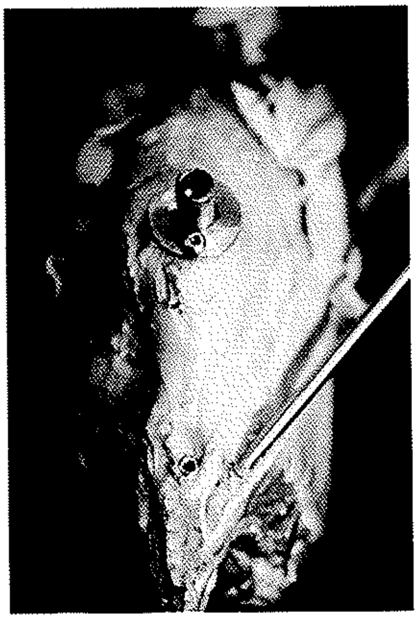

Fig. 3- The tibial tubercle was medialised in the cadaver specimens according to the Elmslie - Trillat technique.

The TTM procedure increased lateral patellar stability significantly (P<0.05) above 20 ° knee flexion, with a mean increase of 52 ± 9%. Figure 4 shows that this did not persist when the knee was extended.

The best results were obtained from a combined LRR plus TTM procedure. The increase in patellar restraining force was now 59 ± 10% for the flexed knee, but also there was now a significant increase of 23 ± 9%, at 0 ° to 10 ° knee flexion, compared to the pathological state (Fig. 4).

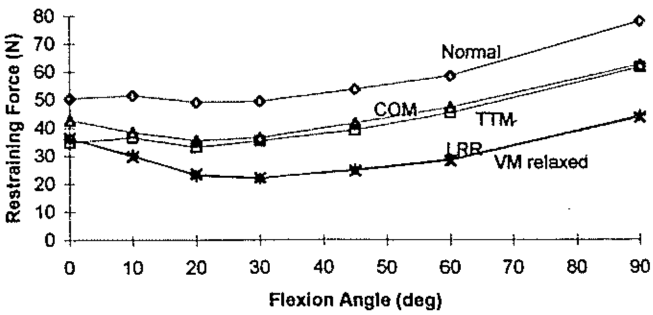

Fig. 4- The force required to displace the patella by 5 mm in normal knee, vastus medialis relaxed (VM relaxed), and following lateral retinacular release (LRR), tibial tubercle medialisation (TTM) and a combined LRR and TTM procedure (TTM + LRR). A total load of 175 N was applied to the quadriceps muscles.

DISCUSSION

The normal function of the patellofemoral joint during flexion is maintained by the complex interaction between soft tissues (i.e., the muscles and retinacular structures) and the congruency of the bones. The resultant force produced by these mechanisms keeps the patella within the groove in the whole range of flexion and prevents subluxation/dislocation. For the first time, the patellar stability has been described quantitatively, in terms of the patellar restraining force. This provided greater insight than recording tracking and contact patterns, which only reveal the movement that occurs after the initial stability has dropped to zero.

It is usually accepted that patellar stability increases with knee flexion, as the patella passes into the trochlear groove. Patellar stability did not change significantly in this study between full extension and 60 ° and 90 ° knee flexion. There is, of course, a major difference between the physiological conditions, when the quadriceps force increases with knee flexion due to the increase of the lever arm of the body weight, and the experimental conditions of the present study in which a constant muscle force was used. The result of the present study agrees with our previous work on the geometry of the femoral groove which showed a constant sulcus angle with knee flexion (12).

A pathological knee extensor mechanism was simulated in this study by relaxing the VM. This represented an extreme form of the common clinical finding of vastus medialis wasting, and thus an appropriate starting point for the experiments. A deliberately abnormal force distribution was used experimentally by Goh and co-workers (13), but in specimens without muscles and retinaculae.

The 47% reduction in force needed to displace the patella 5 mm laterally after relaxing them VM shows that this muscle has an important role in the stability of the patellofemoral joint across the whole range of knee flexion. However, even complete VM relaxation did not result in patellar dislocation in our tests. This is consistent with previous results (1,4,15), suggesting that for patellar dislocation the soft tissue dysfunction needs to be accompanied by a shallow femoral groove. Although it is widely accepted that abnormal muscle forces will cause patellar maltracking, we are not aware of prior work to quantify these significant effects.

The minimum stability in knees with the VM relaxed was at 30 ° flexion, and Goh and co-workers (13) also found this. It has been suggested (1,16) that 30 °flexion is the best knee position to evaluate patellar stability, since patellar subluxation and dislocation often occur around that position. This suggests a link between these problems and vasuts medialis dysfunction.

The LRR alone did not improve patellar stability significantly, and this is consistent with previous tracking and contact pattern studies (4-6). This conclusion, however, may only apply when the problem originates from VM weakness, and not if the lateral retinacular tissues are abnormally tight, a different pathology which will be the subject of further work. Also, the role of the retinaculae may be greater in vivo, due to their proximal attachments to muscles, which might induce increased tension. Krompinger and Fulkerson (2) attributed the effectiveness of LRR to the release of a painful and chronically shortened lateral retinaculum, rather than realignment of the patella. Insall (8) believed that the simplicity of the LRR operation has led to its overuse.

The Elmslie-Trillat procedure, which realigns the distal force vector acting on the patella, was shown to be a powerful means for restabilising the extensor apparatus. After only 6 mm TTM, nearly 50% of the difference caused by complete VM relaxation was recovered. This effect in such an extreme circumstance suggests how larger displacements of the tubercle may lead to overcorrection in some patients. The TTM was most effecive in flexion (beyond 20 °); the change of stability in extension was not consistent. These results are in good agreement with clinical literature (1,7,8).

This study suggests that an isolated TTM can be effective in treatment of patellar subluxation, but that this effectiveness falls towards full knee extension. Since patellar subluxation usually occurs near extension a combined LRR and TTM may be necessary, the LRR being effective mainly in extension.

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