THE EXPERIMENTAL STUDY ON THE INJURED CRUCIATE LIGAMENT OF THE KNEE

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Because instability of the knee joint arises from an injured cruciate ligament, its reconstructive surgery becomes a matter of importance if a full range of motion with satisfactory stability is to be achieved.

Since Hey Groves' reconstructive surgery was first reported in 1917, various modifications have been practiced, but there is no mention of any study of a fundamental nature.

Questions pertinent to this study were:—

1. Whether a grafted fascia or tendon within the articular cavity would structurally last?
2. If so, what kind of histological process would take place during repair?
3. Whether an artificial ligament made from fascia or tendon with some limitation in the diameter is strong enough for the required stability of the knee joint?
4. What kind of core materials are suitable?
5. How the post-operative limitation in the range of motion from such an extensive procedure could be reduced?

In the hope of resolving these questions and discovering some possibility of improving the surgical technique, this fundamental study was undertaken.

In the first experiment the cruciate ligaments of mature rabbits weighing 3 Kg. were removed and fascial strips were bridged in the respective joint cavities of each rabbit according to the Hey Groves' method.

Group A had their limbs fixed in plaster casts till the time of sacrifice; Group B had the casts removed 4 weeks after the operation; and Group C were not immobilized by any casts post-operatively.

The process of the repair of each fascial strip, the reaction to the surroundings, and the secureness of the attachment of the reconstructed ligament in the bony canal were followed up in each group at weekly intervals.

RESULT

Group A:

About 3 days after operation, the hypertrophy of the synovial folds caused them to be forced over next to the grafted fascial strip (Fig. 1). Prior to contact between the synovial folds and the fascial strip, the lining cell layer of the synovial membrane facing the fascial strip fell off spontanously through a degenerative process.

At two weeks the synovial membrane wholly surrounded the entire fascial strip and the grafted fascial strip revealed a degenerative condition.

By the 6th week this degenerated fascial strip had been invaded by young connective tissue with profuse vascularization taking place in the synovial folds. The total absorption of the fascial strip by this connective tissue was completed by the end of the 6th week (Fig. 2).

At first all of the connective tissue had fibre lines running in various directions, but as time went on, two areas appeared: one where the fibre lines ran in random directions, and another where the fascial strip was absorbed by the connective tissue, with the fibre lines running in the same direction as those of the former fascial strip. This was caused by the structural tension between the bony anchorages (Fig. 3).

About the 8th week this fibrous arrangement in what was formerly the fascia became more dense as a result of shrinkage especially of the vessels, and a tiny fissure was observed between the two areas.

By the 10th week the surrounding synovial tissues shrunk forming folds, and the surface became covered with a newly proliferated lining cell layer. A single fibrous cord could be

Fig. 1. Three days after operation, synovial folds near the grafted fascial strip.

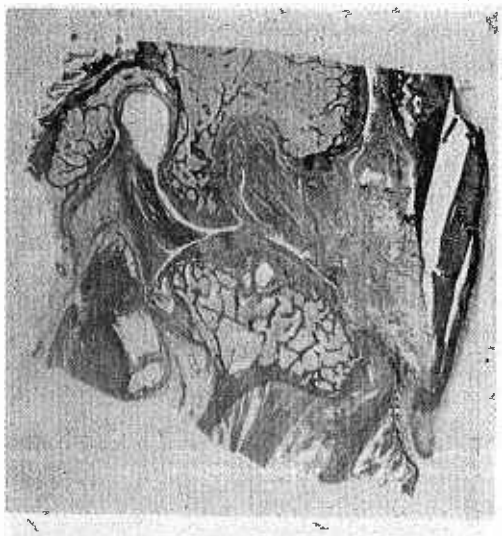

Fig. 2. The sagital gross section of operated knee joint. The grafted fascial strip is almostly absorbed, and the joint cavity is filled up with the synovial tissue.

Fig. 3. The connective tissue which absorbed the fascial strip has fibre lines running in the same direction as those of the former fascial strip.

Fig. 4. Reconstructed cruciate ligament.

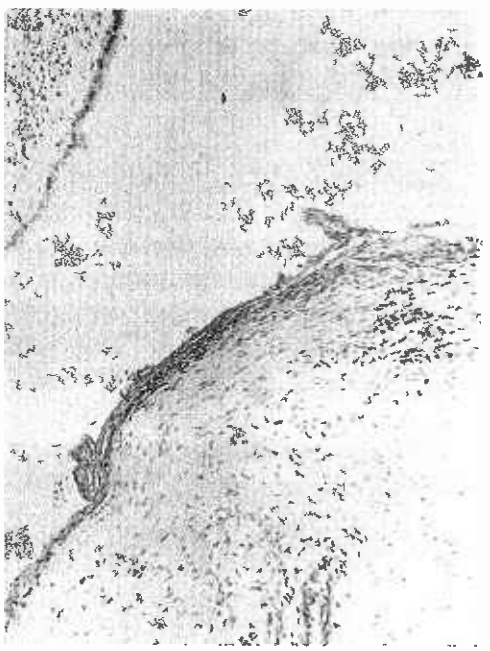

Fig. 5. The reconstructed ligament is covered with the lining cell layer.

observed standing out from the synovial mass filling the joint cavity (Fig. 4).

In addition, the surface of the newly formed fibrous cord was covered with a lining cell layer. (Fig. 5). The reconstruction of the grafted cruciate ligament progressed to completion by the 12th week.

In this repairing process there was no apparent difference between the free and the pedicle graft.

Though the ossification of grafted fascia in the drilled canal can take place by either a fibrous or enchondral ossifying mechanism, in Group A fibrous ossification was prominent. The grafted fascial ligament was thoroughly replaced with bony tissue by the 10th week.

In Group B, the repairing process was much faster than in Group A, especially after the cast was taken off. The progress of reconstruction could be observed according to the following schedule: at the 5th week absorption of the fascial strip: at the 6th week single fibrous cord formation: at the 8th week completion of the process. Enchondral ossification in Group B, was aided by the freedom of the immobilized limbs. It is to be noted that the reconstructed ligaments in Group B were thicker in diameter, denser and stronger when compared with the ones in Group A. This implies that proper stimulation at the appropriate time causes a mechanical adaptation of the repairing process.

The repairing process in Group C is by far the quickest and the most vigorous, when compared with the other two groups. At the 4th week the fibrous cord formation was completed. However elongation and tearing of the newly forming ligament very often occurred. The outstanding feature of this group is seen in the drilled canal. When movement was allowed too early, at a time when no apparent ossification had taken place, the connective tissue was easily pulled away from the canal wall. It follows that neither end of the ligament becomes anchored in the bony canal and that the instability of the knee joint remains.

In the 2nd experiment, the reconstruction of the ligament was performed using silk, catgut, nylon, and stainless wire as core materials. Their merits and demerits will now be discussed.

RESULT

The animal materials, silk and catgut were fairly reactive to synovial tissue so that by the 1st week young proliferated granulation tissue with multiple giant cells surrounded the grafted materials.

This granulation tissue invaded the core materials. However, the absorption and replacement of these materials were so retarded that even at the 6th month, silk and catgut could still be distinguished in the proliferated synovial tissue.

Though a fibrous cord was formed, strong adhesion with the synovial folds due to chronic inflammation produced limitation in the movement and irritation of the joint (Fig. 6).

Fig. 6. When the silk is grafted, the absorption is retarded and the adhesion to the surrounding is conspicuous.

The non-animal materials, nylon and stainless steel wire were much less reactive when compared to the animal materials. Therefore, the granulation tissue surrounded the core materials, but there was no invasion, absorption, nor replacement of these materials. Only a thin membrane of connective tissue formed around the core materials.

CONCLUSIONS

Some noteworthy points are:—

1. In the repair of the cruciate ligament the well vascularized synovial folds play an important role with their marked regenerative potentiality. The grafted materials induce the reactive proliferation of the synovial tissue.

2. (a) When animal materials such as silk and catgut are used, motion of the joint is impaired because of the extensive adhesions arising from the chemical inflammation caused by these materials.

(b) Since non-animal core materials are not replaced by a fibrous cord they can easily be torn or elongated.

In short, there are no satisfactory materials except autogenous tissue in which vascularisation is not a problem. The tissue used should be strong and thick enough in diameter. For this the iliotibial band or tendon is the best material.

3. Since an optimum amount of tension creates a better repair, some motion should be allowed.

The repairing process of the grafted ligament is retarded by a long period of immobilization, producing intra-articular adhesions which subsequently limit motion of the joint. If exercise of the limb is allowed too early, the grafted ligament or the replaced connective tissue will be easily elongated and torn, and the ossification in the canal will likewise be disturbed.

Therefore, it is of great importance to correctly set the time for removing the cast in order to regain the required stability and range of motion. Judging from the result of this study, the most appropriate period of the immobilization is 4 weeks for the experimental rabbit

4. If the surgical procedure is performed with these points in mind, the results of the reconstructive surgery of the injured cruciate ligament should be highly successful.