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Current Aspects of Rehabilitation after Ligament Reconstruction Anterior Crusader

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Abstract

In 1984, rehabilitation procedures were established for anterior knee instability. Since then, these procedures have changed dramatically. Immediate weight bearing, immediate exercise to full extension, and quadriceps exercise on the first postoperative day is just three changes that simplify this rehabilitation process. Many biomechanical and healing constraints remain the same. However, it appears that humans are recovering much faster than animal models used to predict successful treatment of front knee instability. As usual, the pendulum sways and focuses differently on repair ideas and techniques that were not used a few years ago. This article reflects the latest developments in this rehabilitation process.

Keywords: Rehabilitation; Ligament Reconstruction; Anterior Cruciate Ligament; Knee

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Introduction

The huge spread of "at risk" sports activities over the past few years has seen internal knee injuries grow dramatically. At the same time important progress has been made in this field of traumatology, thanks above all to a better knowledge of the anatomical-physiology and the introduction of arthroscopic methods. The affected population can be classified into two broad categories [1,2]. In the first we find patients at a young age, strongly motivated to resume the sports activities previously carried out in the shortest possible time. In the second we find patients in middle-high age groups, who have undertaken the most varied sports activities late and who do not intend to give up [3,4]. All this has entailed, and entails, the need to provide more exact diagnostic responses and therapeutic procedures suited to the different needs of the patients. The purpose of our work is to illustrate the rehabilitation methods used in post-traumatic anterior knee laxity, performed with reconstruction, with autologous patellar tendon transplantation with the "half tunnel" technique [5-8].

By addressing the problem of functional knee rehabilitation, there is a risk of affirming concepts that in a short time could become obsolete and no longer valid: just think of the time of immobilization in plaster casts or orthopedic braces, those without load, and the long hypoactivity of the quadriceps, still required in some protocols. For what has been said, it is preferable to speak of the "philosophy" of rehabilitation of the knee, establishing scientific presuppositions on which to then develop specific methods, which thanks to the continuous acquisitions in the biomechanical field, can be varied [9,10].

Anatomy and Biomechanics

As always, the correct key to the therapeutic interpretation of this joint remains knowledge of anatomy. We will talk about broken L.C.A. isolated or in association with other meniscoligamentous capsule lesions. Considering the knee as a functional unit, we realize that any untreated ACL injury will inevitably lead, over the years, to an aggravation of clinical and subjective symptoms [11-14]. ACL is the primary stabilizer of the knee: it opposes the anterior translation of the tibia (T.A.T) on the femur. From this we can understand how an untreated injury of this ligament inevitably leads to an irreversible worsening of the joint, due to a loss of congruence of the joint heads during the rolling and sliding movement of the femur on the tibia [15,16].

The breakdown of the L.C.A. causes an anomaly of the kinematics that occurs only under stress. Only with the limb resting, or with a contraction of the quadriceps, does an anterior sub-dislocation of the tibial plateaus appear, which is more important in extension than in flexion (anterior laxity in extension). Active sub-luxation in extension causes damage to the articular cartilage, both in life daily and during sports, thus becoming a fundamental factor in the determinism of osteoarthritis. In fact, beyond 30° of extension, the front instability generates an internal tibial rotation, instead of the normal rolling-sliding effect [14].

Surgical Indication

The surgical indications of this pathology are an average severe and clinically not tolerated laxity, an age up to 40-45 years (in addition only in special cases), the absence of serious osteochondral lesions and a strong demand for precluded physical activities.

Surgical Technique

The choice of Anterior Cruciate Ligament(ACL) substitute ranges from autologous transplantation, to ligament prostheses, to mixed techniques (LAD).

In our Orthopedics service for years we have used the middle third of the patellar tendon as the "golden standard" of this surgery, as it has characteristics of high resistance, its removal does not create particular problems to the extensor apparatus and allows a safe fixation "bone to bone" [17-19].

However, there is an objective difficulty in the reconstruction of the ACL due to its complexity in the sense of the large insertion area, its multifascicular and intrinsic proprioception that after a trauma becomes compromised. The technique used is the "in-out half tunnel" technique. Some details of surgical technique such as:

- "Bone to bone" fixation with an interference screw.
- The implant isometricity, with reference to the femoral insertion, which must be as proximal and posterior as possible on the medial face of the lateral condyle.
- The reduction of the friction of the new ligament with the surrounding bone areas through an adequate plastic of the intercondylar throat, have created the conditions for an early rehabilitation while minimizing the risks of failure [20,21].

Surgical reconstruction can be arthroscopic or arthrotomic: in both cases we adopt the same rehabilitation protocol, as the whole course appears perfectly superimposable.

Rehabilitation Concepts

In terms of kinesiological planning, it should be noted that there must be no strict therapeutic references: they may undergo modifications, even substantial ones, based on the functional response and the gradually emerging needs of the individual patient. In any case, the orientation of modern ACL reconstructive surgery is to pre-accelerate functional recovery as much as possible, that is, loading, obtaining full articulation and immediate use of the various muscle groups [22].

All this to eliminate all those negative effects, due to delays in mobilization, which in the past have weighed on the results of this surgery.

We know that the immobilization of a joint involves pathological changes at various levels: cartilaginous, synovial, ligamentous and muscular. As regards the cartilage level, the non-use of the joint increases the deformability of the cartilages by about 42%, their thickness decreases by about 9% and in the superficial areas there is a decrease in glycosaminoglycans up to 48% [23-25].

A modification in the hydration of the cartilage has been described, with the presence of fibro-fatty adhesions on its surface.

At the synovial level, a delayed use of the joint favors the proliferation of fibroadipose tissue, due to decreased synthesis, and determines the onset of adhesions. The so-called "infrapatellar contracture syndrome" has been described with consequent loss of joint in flexion and extension. At the ligamentous level, due to the immobilization, an atrophy of the ligaments and a degradation of the collagen exponentially during the duration of the immobilization itself occurs[26]. Furthermore, a cellular disorganization of collagen is noted, the ligament structure becomes less resistant and the breaking loads decrease by 1/3. At the muscular level, a hypo tone-trophy is noted that varies from 30% to 47%, which occurs very quickly and increases exponentially over time. After only 72 hours of non-use, a 17% loss in muscle fiber height was observed. From what has been said it is clear the importance of the introduction of an "Accelerated Protocol", aimed at preventing these negative effects due to a delay in the correct use of the knee [27].

However, for the purposes of our rehabilitation planning, we must keep in mind the evolution of biological transplants, i.e. the passage of the new ligament through three distinct phases. The first is the avascular necrosis phase, what we call the total protection phase, in which we will have to adopt therapeutic measures in order not to compromise the integrity of the transplant.

The second is the revascularization phase, or partial protection phase, which takes place through the vessels of the tibial and femoral tunnels, through the synovial tissue and Hoffa's body. The third phase is the phase of re-collagenization, induced by mechanical stress, which takes place through a remodeling and orientation of the collagen that transforms from type 1 to type 3, becoming less resistant to attacks by proteolytic enzymes. This is the phase in which the return to sport is allowed [28].

In orthopedic literature there is a certain discordance on the biological evolution of the new bond. Many authors say that only after 15-18 months the ligation process is finished and therefore only then the substitute of the ACL can reach normal mechanical values. There is no doubt, however, that only after three weeks the transplant shows an early metabolic activity, fibroblasts reappear and has a high synthesis capacity.

Summarizing the above concepts, we can say that the aim of ACL post-surgical rehabilitation is to return to the pre-trauma activity as quickly as possible and at the highest levels, minimizing the risks of transplant failure, complications or relapses. Then some questions arise which can be summarized as follows:

- How much tension can be given to the transplant in the initial phase? What rehabilitation techniques to adopt?
- What is the "physiological stress" that transplantation can tolerate? Can we proveit?
- How much and how can this "stress" be increased over time? What is the time delay in the use of the various methods?

We will try to answer these questions and to justify our choice oriented towards an "Accelerated Protocol" of functional rehabilitation based on the following postulates:

- Immediate protected load.
- Early exercises for quadriceps and hamstrings.
- Complete articulation from the immediate post-operative.
- Early return to sports.

Shelbourne KD, et al. (1995)has followed 209 knees since 1987 with an average follow-up of 2 years [29]. The results were assessed with the KT 1000: in a time, series prior to 1987 the knees with a T.A.T (anterior tibial translation)> by 5 mm was 9.6%. Since 1987 after the adoption of the accelerated protocol, the knees with T.A.T> by 5 mm they were 3.4%.

In addition, with the traditionally conservative rehabilitation it has been seen that the incidence of contractures in flexion was between 14% and 32%, while with the introduction of the accelerated protocol the incidence of contractures in flexion was almost zeroed.

Still, while before the incidence of patellofemoral disorders was between 47% and 65%, now it has fallen between 19% and 21%. But, especially with the adoption of the accelerated protocol, there has been no change in terms of stability.

The fundamental aspects to be reconsidered with respect to the past are:

- Immediate recovery of the extension.
- Early use of the quadriceps.

As regards the failure to recover the extension, we know that it represents the most serious and the most common of complications after ACL reconstruction The effects related to loss of extension are: patellofemoral pain with crackles, muscle failure, "Cyclops Syndrome" and arthro-fibrosis.

It is clear therefore, that we must encourage passive extension equal to the contralateral knee from the 1st postoperative day. These concepts, which characterized the American school, and which once seemed heretical (remember that even in the 1980s, the French school outlawed the extension for 3-4 months), are now accepted and desired by all.

The same thing applies to the early use of the quadriceps.In fact, precise indications arrived from overseas, supported by numerous studies and experiments, for an early use not only of the flexors, but also of the extenders, while also in this case the French school was characterized by an almost obsessive conservatism.

Flexors have always been considered, with good reason, real LCA tutors.

Hirokawa S, et al. (1992) described, in the absence of ACL, the anterior sub-dislocation of the tibia as responsible for evoking a rapid response of the flexors, thus indicating the existence of a secondary reflex arc, starting from the muscle and the capsule joint, which directly excites the hamstrings and inhibits the quadriceps [30]. However, it happened that, emphasizing only the work for the hamstrings, 3-4 months after the surgery, a disabling hypotrophy of the quadriceps was observed, with related loss of extension.

The study of anterior tibial translation in a closed and open kinetic chain led to the early introduction of the use of the quadriceps, without thereby compromising the integrity of the transplant [31,32].

We know that working in a closed kinetic chain increases compression and decreases the translational force; vice versa for the open kinetic chain.

This leads to the expectation from the immediate post-operative period of early loading and work for the quadriceps in a closed kinetic chain, as this does not increase the T.A.T.

Jenkins WL, et al. (1997) demonstrated the above by comparing two types of movement in closed kinetic chain (leg-press) and open kinetic chain (leg-extension), evaluating the results in the sense of T.A.T, with the KT1000; the results obtained are these [13]:

- At 30° of flexion: in open kinetic chain the T.A.T. was 4.68 mm and in a closed kinetic chain of 1.26 mm.
- At 60° of flexion: in open chain the T.A.T. it was 1.23 mm and in closed chain 0.60 mm.

From this it can be deduced that the maximum front translation takes place in an open 30° kinetic chain, while at 60° of flexion it is also possible to work in an open kinetic chain reaching a T.A.T.similar to that of the closed kinetic chain, at 30° of flexion.

Furthermore, it has been quantified that active flexion-extensions with loads up to 4.5kg, with maximum joint excursion from 90° to 50°, do not produce any tension on the neo-ligament.

The work for the quadriceps in an open kinetic chain can therefore be considered optimal if performed with:

- Low loads
- Low isotonic angular speeds
- High isokinetic angular velocities
- Limited joint excursions
- Anti-shear (i.e. with distal and proximal support)

In this regard Wilk KE, et al. (1996) have demonstrated how to optimize the work in the open kinetic chain for the quadriceps regarding the isokinetic angular velocity and with regard to the angle of flexion, minimizing the T.A.T [33].

12 knees with chronic anterior laxity were examined, which compared to the healthy limb had a minimum of 4 mm of T.A.T. and a maximum of 12 mm, measured with the computerized Lachman Test at the Orthopedic System Inc. Knee Signature System- OKI KSS (the average difference was 8.8mm).

The modalities with which the Test took place were:

- Distal support to the tibia (1 inch above the malleolus)
- Proximal support to the tibia (3 inches above the malleolus)
- 3 isokinetic angular speeds: 60°/sec, 180°/sec and 300°/sec)

The device used was the Biodex Multy Joint System 2 (Biodex Corporation Shirley, NY. Italian Importer Seteco s.r.l Pieve di Cento) [34].

The results were the following:

- According to the angular velocity, the maximum T.A.T (16.1 mm) was reached at 60°/sec with distal support, while the minimum T.A.T (8.6 mm) occurred at 300°/sec with proximal support.
- According to the bending angle, the maximum T.A.T. (16.1 mm) at 18° of flexion with distal support; while the minimum T.A.T (8.6 mm) occurred at 26° of flexion with proximal support.
- This confirms what many authors have observed in the past and that is that the maximum anterior tibial translation occurs in the last 30° of extension.

Summing up:

- Proximal support to the tibia during exercises for the quadriceps, minimizes the T.A.T.
- The high isokinetic angular velocities (300°/sec) minimize

the T.A.T.

- The "range of motion", which produces the highest peak of T.A.T., is between 30° and 5° of flexion during the work for the quadriceps against resistance.

Methods

Muscle work during knee rehabilitation is based on character techniques, where Isometric, isotonic and isokinetic, which are included in the work program at different times, respecting the biological evolution of the transplant. For what concerns the isotonic work, for several years we have been using the pneumatic oil-dynamic equipment of the Air-Machine Medical Line (Air-Machine srl Case Castagnoli-Cesena) with which the patient can comfortably vary the loads and to observe their work in terms of speed and curve on a special LCD monitor (Ergovision).

All these devices are equipped with devices for adjusting the "range" of joint excursion, in order to adapt the work according to individual needs, also related to the time factor.

We will focus on the isokinetic work analyzing its advantages and times of use.For several years we have been using Biodex isokinetic devices (Biodex Corporation, Shirley NY, Italian importer Seteco srl, Pieve di Cento). With the latest device, the Biodex Multy Joint System 3, we have achieved very high-quality standards for curve analysis.

We summarize the advantages of using isokinetic in:

- Working speed between 0° and 500°/sec.
- Resistances adaptable to all angular degrees.
- Possibility to accurately document (now also with colorimetric maps: Isomap) the deficit in percentage.
- Continuous biofeedback during rehabilitation.
- Maximum operational safety.

For a correct approach it is necessary to brush up on the isokinetic glossary:

- Acceleration time: total time to reach the isokinetic speed in milliseconds.
- Deceleration time: total time to get from isokinetic speed to zero speed.
- Torque: function of force and distance measured, from the rotation axis, from the dynamometer.
- Work: force multiplied by the distance during the entire range of motion. This is the area under the curve.
- Power: ratio between the work and the time taken to carry it out, expressed in watts.
- Peak Torque: highest point reached in the curve during a flexion-extension movement.
- Peak Tq / Body Weight: percentage of maximum strength based on body weight.
- Time to Peak Tq. (TRTD): time taken to reach P.Tq.
- Peak angle Tq .: position of the curve where the P.Tq. is reached.
- Total Work: sum of the work of each repetition in Joules.
- Average Power: ratio between the total work and the time required to obtain it expressed in watts.
- Coefficient of variance: percentage variation within limit values.
- Force decay rate (FDR): represents the decrease of the curve

After having dealt with the glossary, let's now examine the typical curve.

The three fundamental parameters in the analysis of the curve are:

- Acceleration
- Obtaining the Torque (TRTD)
- Curve decay (FDR)

As for acceleration we say that in a normal curve the P.T. is reached in the initial third of the curve.An extension of the time to obtain the P.T. (TRTD) indicates a difficulty in generating muscle contraction.An exaggerated concavity of the curve indicates a difficulty in producing force.The work (i.e. the area under the curve) can vary significantly compared to another curve even with the same PT: this means that we are in the presence of a rapid decline of the curve (FDR), which expresses a difficulty in producing strength for a long time.If we want to answer the three most frequent questions about isokinetic, namely when to use it, how to use it and why to use it, we summarize the basic concept that informs our experience in this regard.As far as the "when" is concerned, it should not be included in the work plan until after about 45 days have passed. from surgery, that is when the revascularization and lamentation of the transplant began.

As for the "how", isokinetic dynamometers are used in this phase, but the operating speeds must all be above 300°/sec, With the precautions mentioned above. As time progresses, lower speeds will gradually be introduced, allowing more and more complete joint excursions.As regards the "why", we consider isokinetic as a fundamental component of the post-surgical recovery of the knee.In fact, it allows the patient to always work below the pain threshold, thus expressing all his muscle potential, and avoiding the most common complication after ACL reconstruction with the patellar tendon, i.e. the patellar proximal insertional tendinopathy (in the explant area).

Lastly, addressing the problems of proprioceptive recovery, we use both the same isokinetic device mentioned above, Biodex System 3, and the Stability System (Biodex Corporation Shirley NY and Seteco srl, Pieve di Cento).By proprioceptive recovery we mean the reprogramming of the neurological systems that aim to recover the orthokinetic sense of the joint, which was lost following surgery. A simple arthrotomy leads to a decrease in receptor functionality, with a consequent decrease in Motor Units used in muscle contraction, which in the extensor system can be assessed in the order of 50%, while in the flexors it is around 30-40%.The joint receptors of Pacino, Golgi and Ruffini are responsible for information about acceleration, deceleration, change of direction and change of position.

They pick up perturbations of speed, pressure and position; they stimulate the afferent branch of the reflex arc, consisting of sensory neurons, which propagate the impulse to the spinal cord or brain stem thanks to the synaptic union with the efferent branch consisting of motor neurons which in turn send commands to the effector organ.

The articular receptors are divided into slow adaptation receptors, present in the superficial layers of the joint capsule, very slow adaptation receptors present in the ligaments and rapid adaptation receptors present in the deep layers of the joint capsule and in the adipose pads. About 1% of the ACL is made up of the three types of receptors.

We distinguish two types of proprioceptivity:

- Kinesthesia: sensation of movement
- Joint Position Sense: perception of the joint position

At *Biodex System* 3 we can carry out two different tests: passive and active. For the passive, the patient is invited to sit on the Biodex chair, bandage it and determine a target angle at 20° of flexion and make the patient perceive it. The limb is then moved passively at a speed of 2°/sec, the patient must press "stop" when he thinks he has reached the predetermined target angle. The degrees of variation between the target angle and the angle obtained are measured.

Regarding the active test, the preparation is the same as the previous test. A target angle at 20° of flexion is determined, the bandaged patient is asked, after an active random mobilization, to stop the limb at the predetermined target angle. Here too the degrees of variation are measured.

Instead, we use the Stability System for both rehabilitation and proprioceptive tests. Used as a rehabilitation, the patient is asked to remain perfectly still at the intersection of the two coordinates and progressively destabilizes the platform in order to make maintaining the position increasingly difficult. With the test, on the other hand, we measure the stability index compared with the healthy limb, i.e. the average deflection is measured in the anteroposterior and medial and lateral directions; this occurs at various levels of stability starting from the easiest and coming to the most difficult. Last, but not least, remember that in this type of pathology we grant the patient, once the sutures are removed, the full load and the walking in water (Walking Hydro System).In this way, the hydrostatic thrust is exploited, so that the person immersed in water, up to the chest, reduces their body weight by about 70-80%.

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