Reinforcement of Tibial Fixation in Anterior Cruciate Ligament Reconstruction Using a Polyester Multi Stranded Long Chain Polyethylene Core Suture Material

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The best tibial fixation technique in anterior cruciate ligament reconstruction remains a challenge to be solved. Due to the increased tension on the graft and the poor bone quality, the slippage of the graft is a determining factor of failure. We propose an alternative supplementary, cost-effective and reliable solution to improve the outcome of the grafts fixation. The results obtained on 10 freshly frozen porcine tibiae were significantly improved (p=0.012) compared to the standard method of fixation. The maximal and mean pull-out force was in conformity with the literature. The bones and tendons used simulates the real human ones, thus the results encourage us to extend the application of the method in clinical cases.

Keywords: anterior cruciate ligament, tibial fixation reinforcement, graft slippage

Anterior cruciate ligament reconstruction of the knee implies a graft that is fixed to the femur and tibia by different methods [1]. Usually the femoral attachment is a suspensor mechanism and the tibial one is made with an interference screw. The screw is biocompatible, absorbable, and assures a tight connection between the graft and the bone [2].

The tibial fixation is the weakest link in the whole reconstruction system. This is due to the fact that the tibial bone density is lower than the femoral one; and the great forces applied to the graft and implants in this region. It has been proven that during repeated cycles the graft tension diminishes, due to the slippage of the graft besides the interference screw. The result will be an increased laxity of the graft and a low functional outcome [3].

This is the reason why supplementary fixation devices have been used on the tibial side. The usage of additional metallic fixation devices improves the graft’s performance. The great disadvantage is the local tissue irritation generated by the metal and the interference with magnetic resonance imaging devices [4, 5], not to mention the supplementary costs of the implants.

The aim of this article is to present an alternative to the standard supplementary tibial fixation reinforcement.

Experimental part

This study was performed on 10 fresh frozen porcine tibiae. The porcine model was chosen as it replicates the density and anatomy of the human one. The bones had no muscle or ligaments attached the only soft tissue still present being the anterior cruciate ligament tibial insertion. As a reconstruction graft we used porcine flexor digitorum tendons.

The tendons were prepared in a standard fashion as a double loop. Each end was then sewed with a non-absorbable, braided suture (FiberWire, No.2, Arthrex, Naples, Fl.) in an interlocked manner (Krakow type) [6]. FiberWire is a braided long chain polyethylene suture surrounded by a polyester jacket. The construct gives a better performance, offering a higher resistance force, lower erosion and eliminating any possibility of knot breakage. Studies show that, when compared to other types of sutures, FiberWire has superior results on all parameters tested, with significantly less elongation [7].

In order to drill the tibial tunnel, we used a standard 55^0 angle anterior cruciate ligament reconstruction aimer [2,5]. At first a guide wire was placed in the center of the stump of the native ACL. Then a tibial tunnel from antero-medial side of the tibial metaphysis was drilled, according to the graft size.

The graft was then inserted, leaving 2 cm out of the tibial spine, fixing it in the tunnel with a cannulated bioabsorbable interference screw (noncrystalline poly-L-lactic acid, Arthrex, Naples, Fl.). The PLLA screw acts as a ductile material, through constant tension it undergoes deformation, elongation and in the end rupture. The PLLA performs in the same manner as a vitreous polymer, with a mean Young’s modulus of 1564 MPa and a mean elongation at break of 8.7% [8]. The screw has an axial canal and a flat head and is designed for both bone and

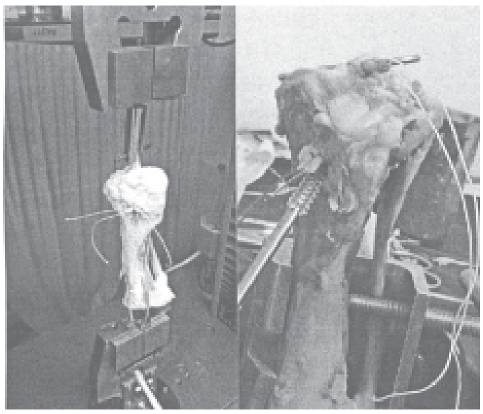

Fig.1 Preparing and testing the grafts

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soft tissue fixation. It needs a tapered hexagonal screwdriver. The osteoconductive material promotes bony ingrowth as the screw resorbs, and should be less reactive to the surrounding bone. The screw was one millimeter larger than the diameter of the drilled tunnel [2,5]. This group was called group one, representing the standard fashion of preparing the tibial side in ACL reconstruction.

In the second group with the supplementary fixation, we introduced an extra suture (FiberWire, No.2, Arthrex, Naples, Fl) through the axial canal of the screw. At the articular end a strong knot was made and at the tibial end the suture was tied with the ones used for sewing the graft ends. We imagined this procedure to be a direct opposition to the upward force distributed on the graft, and also an indirect mechanism by shifting laterally the screw, thus blocking the graft slippage.

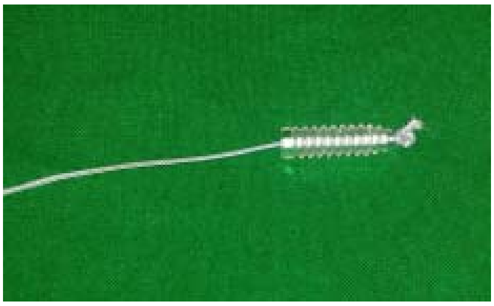

Fig. 2. The Interference screw with the supplementary fixation

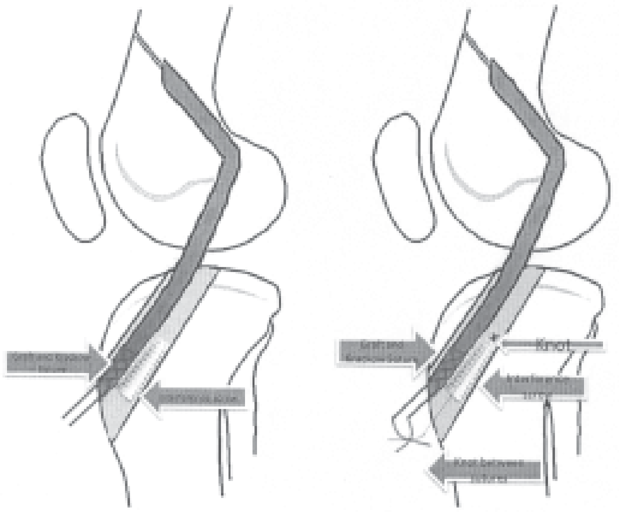

Fig. 3. The standard and the supplementary fixation

We used for testing a Zwick/Roell 005 unit (with a maximum loading cell of 5kN) to evaluate the tensile strength. The porcine tibia was fixed distally with an iron rod passed through a hole in the bone and proximally through the tendon's loop. A pull-out test was carried out with a speed of 10mm/min.

The Mann-Whitney *U*-test was used to compare the grafts maximal forces.

Results and discussions

Figure 6 presents the mean maximal pull-out force registered in the two groups. There is a significant difference between them (standard fixation 473.105N versus 694.503N in the alternative group) with $p=0.012$.

The graphics demonstrating the mean slippage and strength seen in figures 4 and 5 have a different pattern. In the standard group, after achieving the maximal force, there is an abrupt decrease in the forces further obtained.

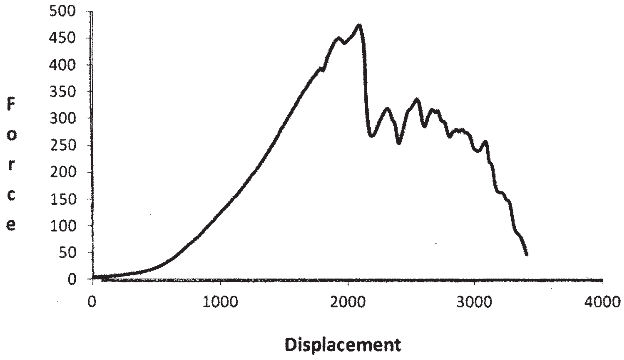

Fig. 4. The mean displacement/strength dynamics achieved by the standard fixation

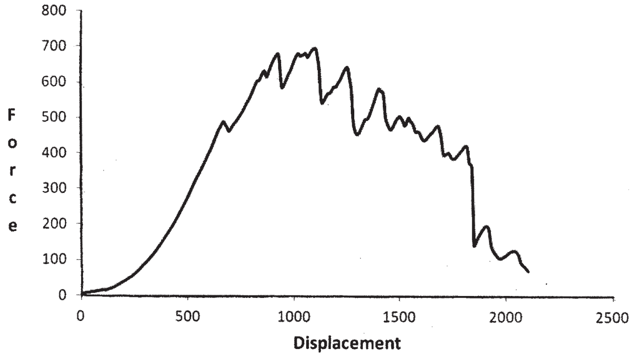

Fig.5. The mean displacement/strength dynamics achieved by the reinforced fixation method

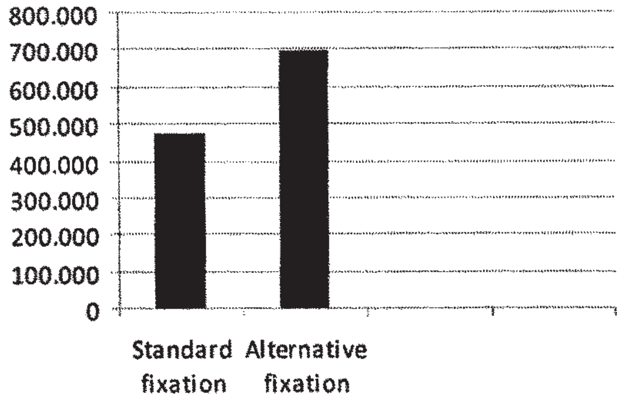

Fig. 6. The mean maximal forces

In the alternative fixation group, there is a "saw blade" type of graphics. The supplementary suture material passed through the axial canal of the screw and tied to the graft, allows at each thread of the screw, during the slippage, to obtain an almost maximal force, until the final breakage of the wire.

Many studies have been performed in order to obtain a better outcome in the tibial fixation of soft tissue grafts [9,10]. Some authors have suggested that cortical fixation is a stronger construct; some believe that aperture fixation gives a more effective fixation device [11,12]. The main disadvantage of these techniques is the irritation of the surrounding soft tissues accused by the patient [10]. Recent studies have proposed the usage of a knotless anchor to obtain the same cortical fixation, thus eliminating the hardware problems [13,14]. Although a good mechanical solution, this method raises the costs of the surgical technique.

Thus we imagined a simple, cost-effective and a reliable solution to achieve the same biomechanical result. The maximal forces of 947.553N, as well as the mean one, are in conformity with similar studies [11,13] of alternative tibial fixation reinforcement.

Limitations of this study are represented by the bones and tendons used, and the type of experimental mechanical stress applied to the graft-bone construction. Although porcine bones and tendons have been compared with those in humans, there are still some differences in density and elasticity [15]. We consider human material to be a better substitute, but with less chances of finding the necessary testing samples. As far as the mechanical stress, it was only possible to apply a unidirectional force [16]. In a real situation, there is also a rotational force that affects the graft-bone connection.

Conclusions

In conclusion, the need for a supplementary tibial fixation in anterior cruciate ligament reconstruction represents a real problem that needs to be taken into consideration during clinical practice. The solution provided is a safe, cost-effective, reliable technique, which creates the premises of applying it into daily activity.

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