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EXPERIMENTAL STUDY OF THE PULLOUT FORCE AT TIBIA LEVEL IN ACL RECONSTRUCTION WITH INTERFERENCE SCREW

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Abstract: The results after ACL reconstruction are depending on several factors: graft choice, tunnel positioning, graft fixation. No fixation system of the graft is as strong as the native ACL insertion. For the ACL reconstruction with STG graft, tibia fixation is considered to be the weak link. The aim of the paper is evaluation of the direct interference screw fixation of a quadruple hamstring (STG) graft. The biomechanical characteristics and the mechanism of failure were evaluated in order to prove which is the safest combination regarding the inclination angle of the tunnel and the screw dimension.

1. INTRODUCTION

The structure of the human ACL and its dynamic role is complex . Therefore its reconstruction with a simple graft cannot approximate the native ACL. The ACL fibers are twisting among each other during flexion and are not isometric. The graft that can be used has different origins but the most frequent used are: patellar tendon (BTB), hamstring tendons and allografts. When the graft is chosen there are to be considered both the advantages and disadvantages of each.

Figure 1. BTB GRAFT

The BTB graft (figure 1) was for long time as the "golden standard" considered because of its strength and bone to bone healing. The multistrand grafts like the four strand hamstring graft approximate much better the complex structure of the native ACL and can offer a better function to the knee. For the BTB graft there is a bone to bone healing which takes place in 4-6 weeks. In case of soft tissue grafts the secondary fixation to the bone tunnels is slower and depends on several factors.

Figure 2. STG GRAFT

Several criteria have to be considered when making the decision: biomechanics properties, the biology of healing, easy graft harvesting, the strength of fixation, the donor morbidity and the patient return to the previous activity. Graft harvesting must be followed by minimal donor morbidity. Anterior knee pain is frequently associated with the ACL reconstruction with BTB grafts

The initial graft fixation after ACL reconstruction is mechanical. It must assure the stability until the biologic integration takes place. No fixation system is as strong as the native ACL insertion. For the BTB graft there is a consensus that its fixation is strong and safe. For the STG graft (figure 2) such a consensus, regarding the ideal method of fixation, does not exist. Tibia fixation is considered to be the weak link.

The purpose of this operation is to return the patient to the specific level of physical activity previous to trauma. Therefore the rehabilitation protocol is essential and it starts immediately after surgery. It has to be continued for a long period of time even after restarting specific sport activities.

In the last years, with the progress of the surgical techniques, methods of fixation and experience the rehabilitation programs are beginning to be more and more aggressive. For the time being there is no consensus regarding the best protocol but it is stated that this has to be patient specific.

The progress in tibia fixation of tendinous grafts and the reduced morbidity after hamstring harvesting increased the number of operations in which STG tendons were used.

Several clinical studies that compare the two grafts were performed by different authors but there are heterogeneous results because of different harvesting techniques, preparation of the graft, tunnel placement, fixation type, rehabilitation protocol and surgeon experience.

One of the controversial topics in anterior cruciate ligament (ACL) reconstruction remains the choice of its fixation. Until biological integration, the graft is primary fixed with a mechanical device.

2. EXPERIMENTAL RESEARCHES

The main study aproached in this article is a biomechanical study about LCA reconstruction, using STG grafts and simple fixation with interference screw alone.(figure 3)

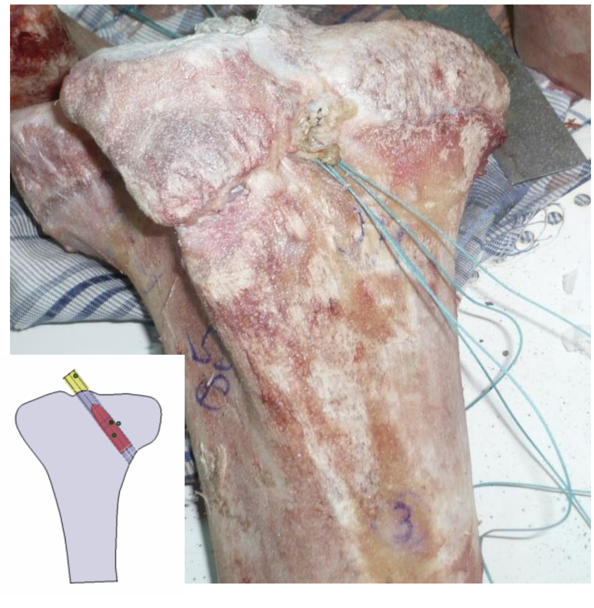

Figure 3. Standard fixation

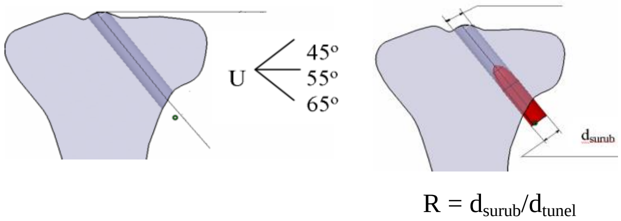

Figure 4. Input variables

The exit variables during this experiment are the main traction force – maximum value and the evolution of fixation forces from the starting point of the loading until the system failure.

We studied the way in which the inclination angle of the tunnel (U variable with three level: 45°, 55°, 65°) and the screw dimension (diameter tunnel/diameter screw – R variable with two level 1 and 1,1) influence the STG graft fixation.(figure 4)

For achieving the experimental researches we used 6 tibia of bovine origin, 6 semitendinosus and 6 gracilis human tendons prepared in a four bundle fashion. The STG grafts were prepared in accordance with the medical protocol.

The anatomical fixation of the graft was made with resorbable interferences screws Inion type. The standard fixation with an interference screw consists of its introduction into the tunnel, parallel to the graft, compressing the soft tissue graft to the tunnel walls (figure 3). The standard fixation is an anchor with no supplemental fixation.

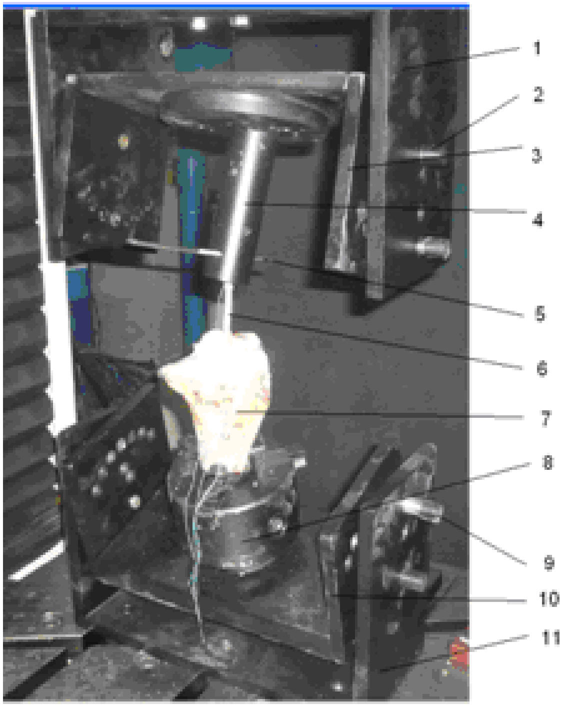

Figure 5. Experimental stand

The experiments were performed on the universal tensile, compression and buckling testing machine Instron 5587 (Maximal force 300 kN) with a special device attached.

The experimental stand is made of the following components: (figure 5): 1 – Fixed superior plate; 2 – Superior fixation pins; 3 – Mobile superior plate U; 4 – Femur orientation and fixation elements; 5 – Graft traction pin; 6 – graft piece test; 7 – Tibia piece test; 8 – autocentering device; 9 - Inferior fixation pins; 10 - Mobile inferior plate U; 11 - Fixed inferior U plate (figure 5).

The tibia piece test 7 is orientated and fixed in autocentered device and the graft piece test is fixed to superior side of the stand thru traction pin (5).

In order to determine the right number of experimental proceedings, we took into consideration that all the variation levels of the variables will interact within all the possible combinations. For each loading condition three observations will be made and the average will be calculated. As a result, we can perform a statistical analysis and create a regression equation which will express the dependency of the Fpmax to the U and R parameters.

Table. 1 Experimental results

Nr.crt.	R	U	Fpmax
1	1	45	363.503
2	1	55	339.804
3	1	65	327.956
4	1.1	45	594.089
5	1.1	55	501.872
6	1.1	65	455.764

Data obtained after applying the testing protocol was statistically analysed in order to eliminate the aberrant results and to verify the normal distribution of the data. The experimental results are presented in table 1. Figure 6 shows the 3D variations of the maximal force keeping an account of all the input variables. For the maximal load dependence the regression equations were calculated as a second degrees conic.

The equations are inserted in the graphical representations.

Regarding the evolution of fixation forces from the starting point of the loading until the system failure, graphical representation were achieved for each loading conditions.

In figure 7 superposed diagrams of the fixation forces in relation to deformation for each value of tunnel angle were shown.

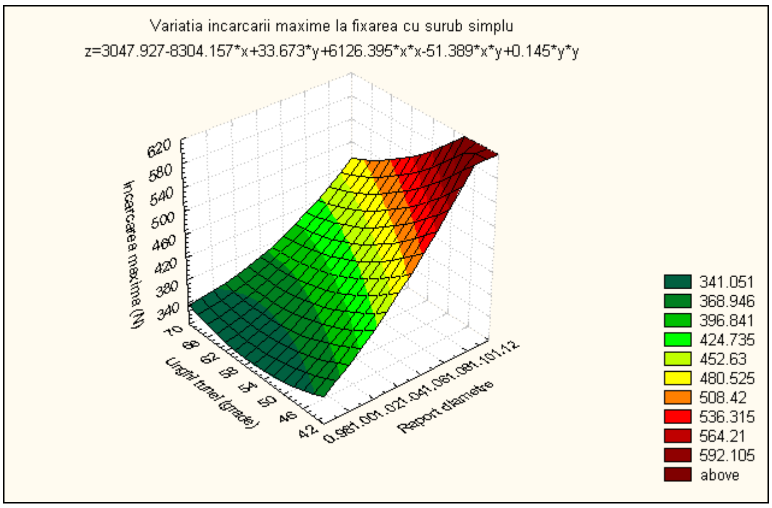

Figure 6. Maximal load variation

After the experimental research resulted the following conclusions:

- the failure point of the graft is around a 14 mm of deformation;
- in all configuration after Fmax value was reached the system had a short deformation (2-3 mm);
- The diagram for 55 degree had a different shape compared to the other two diagrams. It can be seen a slow failure of the system..
- For the values of the R=1,1 and U = 45 degree we obtained the higher value of the traction force.

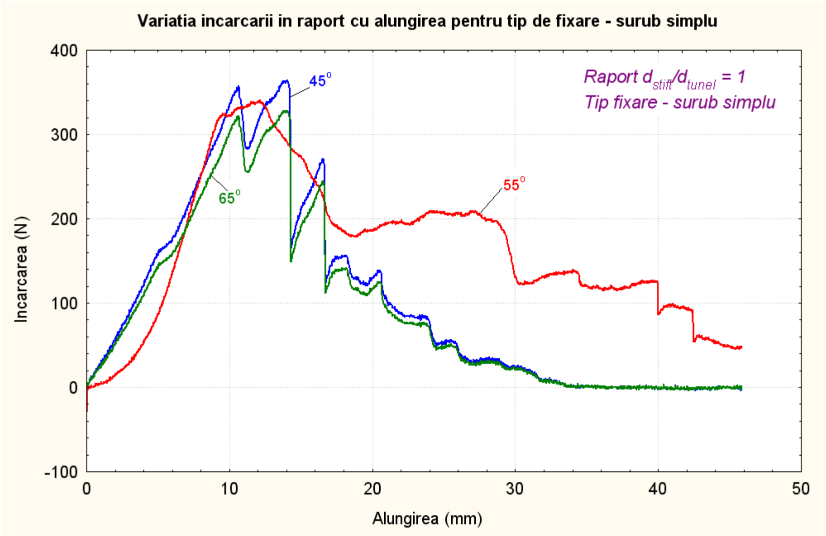

Figure 7. Evolution of the fixation force for each value of the angle tunnel

3. CONCLUSIONS

The incidence of ACL lesions is high and continuously growing because of the permanently growth of performance and recreational sports practitioners.

There are multiple graft choices in the ACL reconstruction. The BTB graft and the STG graft are the most used. The harvesting technique of the STG tendons is much easier and less aggressive.

There was no rupture or damage of the graft in any of the studied configurations. All the grafts resisted to the applied traction and shear forces.

All the presented results show that STG grafts are reliable and capable of clinical results at least as good as the BTB grafts with the advantage of a lower local morbidity. To obtain these results all the principles have to be rigorously respected and the surgical technique has to be meticulous with respect to all technical details.

4. ACKNOWLEDGEMENTS

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References:

1. Cofaru I., .Oleksik M., Cofaru N., Roman M, Fleaca R., Academic Journal of Manufacturing Engineering, Timisoara, 2010
2. Milojevic Z et al. (2010), System for 3D Aproximate Model Generation of the Femur and Screw Built Into Human Knee. Academic Journal of Manufacturing Engineering, vol 8, issue 1/2010, Timisoara
3. Roman M., Cofaru N., Oleksik V., Pascu A., Deac C., Baier I., Fixarea tibială în ligamentoplastia LIA cu tendoane semitendinos şi gracilis (STG) – studiu biomecanic., Revista de Ortopedie şi Traumatologie SOROT, ISSN 148-150, vol. 19, nr. 3/2009
4. Roman M., Fleaca R., Cofaru N., Oleksik V., Pascu A., Deac C., Baier I., Diagnosis and management of partial ACL lesions, 11th EFORT Congress Madrid, 2010.