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CAD MODELING OF MEDICAL DEVICES USED IN ORTHOPEDICS

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***Abstract*—**In this paper we will present the anterior cruciate ligament reconstruction surgical operation and the surgical device used for guiding the drill for osteal tunnels. The objective of this study is to create a surgical guide device used for guiding the drill which will have a better fixing on the bone. We will start with a short description of the anterior cruciate ligaments reconstruction surgery and we will present a common surgically drill guide used in creating the osteal tunnels. The 3D model of the drilling device was created in Catia V5R20 and the tibia model was obtained by scanning.

***Keywords*—**device, ligament, knee, reconstruction

I. Introduction

THE human body is comprised of many joints including the ankle, the knee, shoulder and the elbow. Each of these joints has two bones, connected with a ligament. A ligament can become stretched during time because of the over stressed movement or an injury. When this happens, the ligament reconstruction is needed [1].

The incidence of anterior cruciate ligament (ACL) injuries increased in recent years due to increased sports activity among people older than 40.

Ligament reconstruction typically reestablishes joint stability through a bone-tendon connection. A tendon is taken from another part of the body and is woven through bone tunnels that have been drilled in each of the bones of the joint, and the tendons are usually secured to the bones of the joint.

Because of the forces that act on the knee can damage the knee ligaments.

A ligament rupture can be partial (just some of the fibres that make up the ligament are torn) or complete (the ligament is torn trough completely).The majority of knee ligament injuries are sprains and not tears and they tend to settle down quickly [2].

There are four bones around the area of the knee joint: the thigh bone (femur), the main shin bone (tibia), the outer shin bone (fibula) and the knee cap (patella). But the main movements of the knee are between the femur, the tibia and the patella. Tough connective tissue (articular cartilage) lines the ends of the tibia and femur and the back of the patella around the knee joint. The articular cartilage reduces friction between the bones of the knee joint and helps smooth movement between them.

There are a number of different things that can cause injury to the ligaments in the knee:

1) a direct blow to the knee or knock into something with the knee;

2) the knee may be moved outside of its usual range of movement: during a fall or during sport

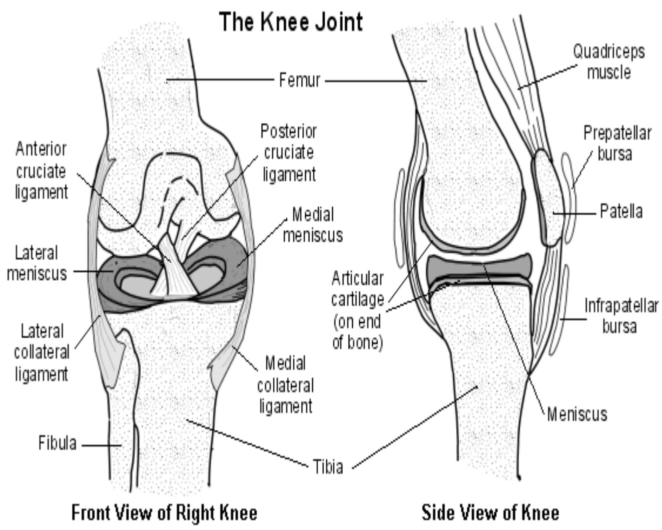

Fig. 1. Anatomy of the knee joint [3]

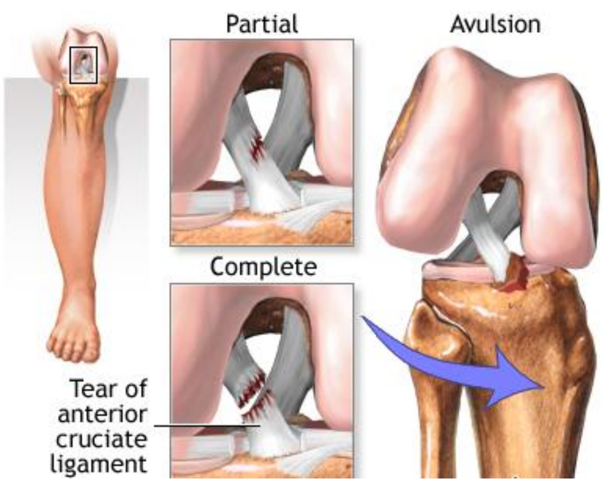

Fig. 2. Mechanism of ACL fracture [4]

Fig. 1 shows the anatomy of the knee joint and in Fig.

2 is showed the mechanism of the ACL fracture.

The joint reconstruction ligaments existed since 1974 and it was called “Tommy John surgery”.

During this time, various devices have issued relating to ligament reconstruction.

The principal reason for ACL reconstruction surgery to fail is misplacement of the graft fixation tunnels. That occurs because of the ACL is placed awkwardly within the knee joint, and is difficult to judge the exact positions needed, even when looking through a modern arthroscopic camera system. Recognizing this, surgical instruments have evolved to try to make a choice of tunnel position less subjective, but that approach has not developed to the point where errors are avoided.

The steps in ACL reconstruction are:

1) *selecting and harvesting the graft;*
2) *preparation space receiver;*
3) *drilling tunnels;*
4) *introduction and graft fixation;*
5) *postoperative functional recovery.*

There are three types of ACL grafts commonly used. These include patellar tendon, hamstring tendon, and cadaver (donor) grafts.

The first step of surgery is to insert an arthroscope into the knee joint to inspect the damage done to the joint. The doctor will confirm the diagnosis of the ACL tear, and also inspect for other damage. The meniscus, cartilage, and other ligaments can be inspected for damage that may have occurred. It is common to treat meniscus tears and cartilage injuries at the same time as performing ACL reconstruction.

Once ACL tear is confirmed, the graft must be obtained, a process called “harvesting” the graft. In the case of a donor graft, the tissue must be thawed. In cases where the graft is coming from the patient having the ACL reconstruction, an incision will be made to obtain the tissue.

After obtaining the graft, the tissue being used to create a new ACL is prepared to be the proper length and width. Some timing may be performed to ensure the proper size of the graft. The graft is then set aside until the knee is ready for the new ACL.

The next step is to create a place for the new ACL to sit within the knee in the tibia. The ACL is right in the center of the knee joint, and needs to be attached to the bone and above and below the joint. Therefore, the new ligament must start within the end of the thigh bone and end within the top of the shin bone.

A drill is used to make tunnel in the shin bone. The end of this tunnel in the knee joint is directly where the ACL should attach to the shin bone.

Trough the tibial tunnel just created, a drill is passed directly to the middle of the knee joint. A second bone tunnel is made from inside the knee up to the end of the femur. This bone tunnel will hold one end of the new ACL, and the tibial tunnel will hold the other.

With two bone tunnels –one in the end of the femur, and another in the top of the tibia- the new ACL graft must be passed into position. A large pin is passed through both bone tunnels, and attached to the end of the pin in the new ACL. The new ACL is pulled up into the femoral tunnel so one end can be secured into the femur. The other end is now in the tibial tunnel, and the center portion of the graft is in the center of the knee joint taking the places of the old ACL.

With the ACL graft in position, the graft must be solidly fixed in its new position. There are several ways to secure the graft. One common way to do this is to use a screw to hold the graft end within the tunnel. The screw can be made of metal, a plastic dissolvable material, or a calcium-based substance that turns into bone.

Once the graft is solidly fixed on the femoral side, tension is placed on the end of the graft, so the new ACL will be tight. The tibial side of the new ligament is then fixed, similarly to the femoral side. Again, different materials may be used to fix the graft into position. Over time, the graft will be heal to the surrounding bone, making the fixation devices unnecessary.

Occasionally, a prominent screw or staple that was used to hold the graft in position may be removed after about a year. If no causing problems, these materials are usually left in place.

In this paper will be presented a surgical drill guide device for drilling an angled osteal tunnel having a support rack at the fist and a second end; a drill guide sleeve having a passage for receiving a drill there trough, the drill guide sleeve being adjustably securable and positional on the rack between the first end and the second end of the rack; and a guide component secured on the first end of the rack, the guide component having a suture seizing mechanism for seizing a suture .

This device will be improved with an additional fixing screw in the area where will be in contact with the tibial plateau. The background of adding this additional screw is to have a better fixation for the device on the tibial plateau.

II. ANTERIOR CRUCIATE LIGAMENTS RECONSTRUCTION

The anterior and posterior cruciate ligaments in the knee assist in providing stability to the function of the knee. The ligaments control gliding, sliding and rotation of the knee. Considering this issues, the anatomic origin and insertion of both of the ligaments is crucial. Often the anterior cruciate ligament (ACL) becomes ruptured or torn, requiring replacement and reconstruction of the ligament in order to restore normal usage of the knee. When the ACL is restored or replaced, the ACL or a substitute synthetic or harvested graft must be reattached to the bone. The ACL graft is anchored in place either inside or outside of osteal tunnels or passages formed in the tibia or femur. It is preferential to locate and drill the tunnels at precise locations, so the ACL will be reattached at the natural location because the graft will be implanted in the optimum position. If a ligament construction is performed in the appropriate location, then normal motion and stability can be restored. Otherwise, the ligament will eventually be too loose or too tight for normal function.

The positioning devices are needed to ensure that an osteal tunnel has a precise drill exit point. Often, surgeons are required to work in a "sensible" area, in which are nerves and with this positioning instruments are not interface with this delicate areas.

Usually are used 3 types of angled tunnels. In Fig. 3. are shown the possible tunnels : at 45, 55 and 65 degrees.

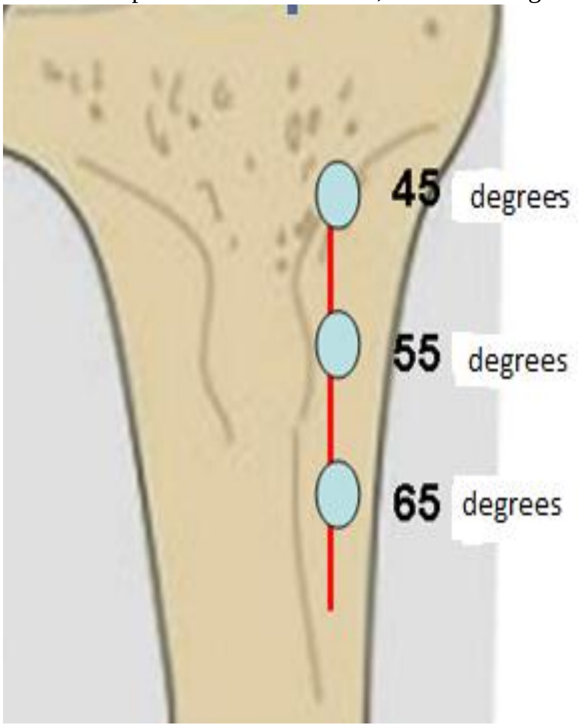

Fig. 3. Drill tunnels [5]

III. DESCRIPTION OF THE SURGICAL DRILL DEVICE

Fig.4. is a typical prior surgical drill device. This device has three primary components: a guide sleeve, a guide tip and a support. The drill bit is passed through the guide sleeve (component 1) and the guide tip (component 2) will guide the direction of the drill bit. These two components are mounted on the rack (component 3). The guide sleeve and/or the guide tip are typically slidably mounted on the rack, which may be arcuate, such that different angles of osteal tunnels can be drilled through the bone. The guide sleeve can be also displaceably mounted on the rack such that different bones with different sizes.

With nr.4 is represented the osteal tunnel and with nr.6 is represented the guide wire and with nr.5 the bone (the tibia).

Currently, there is a need of devices and methods for creating angled osteal tunnels in conjunction with human ligament, muscles and tendon repair that allows users to be both accurate and flexible, as wells as the devices to simplify surgery, improve surgical devices, and minimize errors. There is a further need for intraosseous devices and methods for creating osteal tunnels and retrieving sutures from within osteal tunnels without having to see or visualize within the bone or osteal tunnels [5].

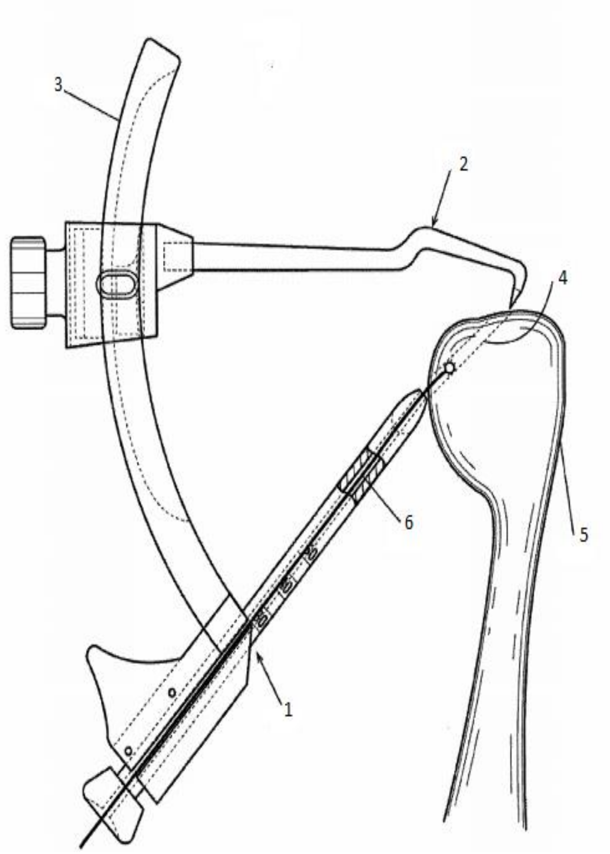

Fig. 4. Surgical drill guide [5]

IV. CAD MODELING OF THE DRILLING DEVICE

For CAD modeling of the drilling device we used CatiaV5R20, part design and assembly design.

The first step was to obtain the 3D model of the bone which will be drilled for the cruciate ligament reconstruction.

We obtained the 3D model of the tibia, which was the first scanned with a 3D scanner.

The next step was to create the 3D model of the drilling device, the typical prior.

For creating the 3D model of the surgical drill guide we started with the parts shown in Fig. 4. First we created the rack, after this, the guide sleeve and the guide tip. These components were created in module "Part design" and after, were assembled [6].

The model obtained is shown in Fig. 5.

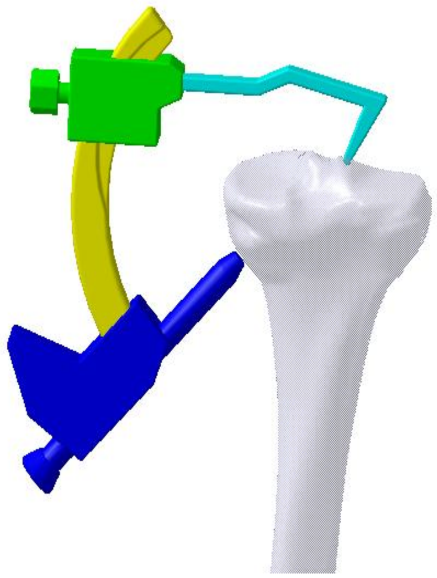

Fig. 5. Surgical drill modeled in CatiaV5R20

V. Improvement of the drilling device

At this typical prior drilling device we propose a new fixing method of the guide tip. This guide tip will be fixed with a screw for a better fixation. Also the guide sleeve will have the possibility to move at different angle values.

In Fig. 6. is represented the new device improved with the fixing screw (position nr. 6). We used a M7 screw, with the length 50.

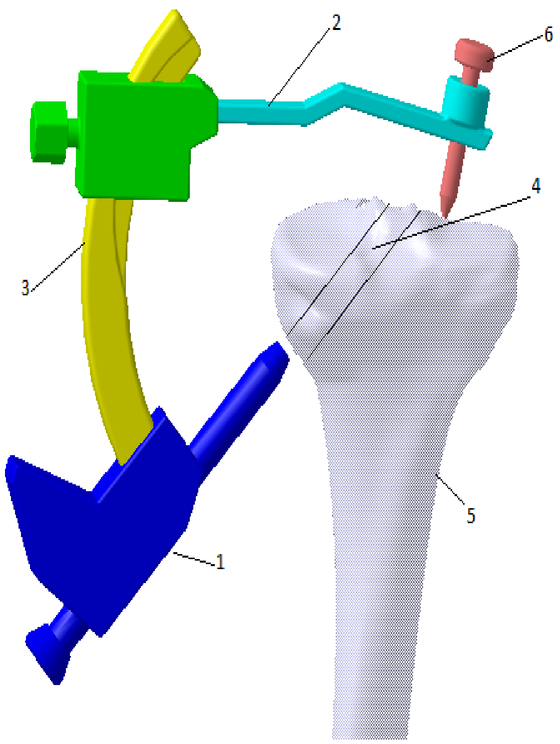

Fig. 6. Surgical drill with fixing screw

This surgical tool comprises a guide component 2 mounted to the end of the rack 3 which may be arcuate in shape, and a drill guide sleeve 1 slidably mounted on the rack 3, which is capable of being securely positioned about the rack 3, toward either end. The guide component 1 facilitates the drilling of an osetal angled tunnel 4, drilled from a first surface of the bone to a second surface. The fixing screw 6 will keep the guide component 2 in the right position.

VI. Conclusion

This study threats the description of the anterior cruciate ligament reconstruction surgery and also the improvement of the drilling device used in ACL reconstruction.

Drilling the osteal tunnels is an important step in ACL reconstruction. In this study is showed the classical device used for this step (drilling the tunnels). The new device will have more flexibility to create bores at different angles and also a better stability of the drilling device by improving a better fixation.

Creating an additional fixing screw for a common surgical drill device we will improve the fixing of the drilling device on the bone. In this way, we will have more precision in drilling the osteal tunnel and also we will have a better guidance of the drill.

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