The Use of Bioabsorbable Interference Screws in Reconstruction of the Anterior Cruciate Ligament of the Knee

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Over the last years the use of bioabsorbable materials in orthopaedic surgery has increased exponentially. One of the first surgical interventions to take benefit from these absorbable materials was the reconstructive surgery for the anterior cruciate ligament (ACL) of the knee, meaning the use of interference screws for the primary fixation of the ligament graft. The aim of this paper is to present the main types of screws of this kind, used in current practice, the preferred manufacturing materials and to evaluate the standard implantation procedures in terms of the stability they ensure to the ligament graft.

Keywords: bioabsorbable screws, ACL reconstruction, ligamentoplasty

The use of metallic implants (synthetic, bioinert) in orthopaedic surgery, besides being accompanied by a series of complications or impediments (migration, infections, radiopacity masking the osseous tissue, foreign body response from the immunitary system), involves a new surgical intervention for the extraction of the implant. In a survey study conducted on a group of patients with fractures requiring osteosynthesis, 95% of the persons inquired answered that they would prefer a bioabsorbable implant, in order to avoid the subsequent hardware extraction surgery [1].

The cruciate ligaments of the knee, anterior cruciate ligament (ACL) and posterior cruciate ligaments (PCL) ensure the stability of this joint in a sagittal plane. Complete lesion of one of these ligaments determines a degree of instability of the knee, including problems related to direction change, braking and controlled torsions of this joint. These functional disabilities restrain the patient from practicing advanced sport activities, and in case of professional athletes, they can not return to the same level of physical activities, unless they undergo a ligament reconstruction (ligamentoplasty), usually with an auto-graft from the patellar tendon (bone-tendon-bone technique), or from the semitendinosus and gracilis tendons (hamstring technique).

Bioabsorbable interference screws (fig. 1) used in fixing the grafts for ACL reconstruction have been used in current practice for some years now, as a result of their obvious advantages:

- they allow subsequent MRI investigations without interfering with the magnetic field of the device [2].
- in case of ACL reconstruction reintervention (revision), the presence of a metal screw makes drilling a new tunnel an almost impossible task. If the previous operation was performed using a bioabsorbable screw, by the time of the reintervention it has probably already been absorbed or was replaced by osseous tissue. Should it still be present, the new hole can be drilled through it.
- absorbable screws, due to their low degree of hardness (lower than that of metal) do not present the risk of sectioning (lacerating) the ligament graft during their implantation [3].

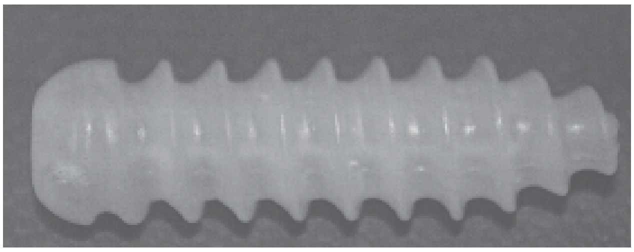

Fig. 1. Bioabsorbable interference screw

The main disadvantage of absorbable screws resides in their lower mechanical resistance (compared to metallic screws), which can be responsable of breakage, especially during their insertion in the tunnel [4]. In order to prevent this undesirable incident, improvements have been continuously brought to the screw-driving system and, more important, to the manner in which the tightening force is transmitted to the entire screw.

Experiemntal part

Materials

Biocompatibility and bioabsorbtion of orthopaedic implants have been the object of numerous studies, beginning with the '90s [5]. The most frequently used and studied materials remain polyglicolic acid (PGA) and polylactic acid (PLA), along with their co-polymers.

PGA is an intensely crystallized, hydrophilic material. Degradation and loss of its mechanical resistance occur early after implantation, leading to an early loss of fixation. The transition temperature between the malleable and the glazed form of the material is 36 degrees Celsius, meaning only one degree bellow the normal human body temperature. This means that the material must be warmed up to above 36 degrees during surgery, shaped and then cooled down before implantation (a process that inadmissibly extends surgery time).

PLA displays in the composition of its monomer (lactic acid) an additional methyl group, which increases its hydrophilic properties. The two enantiomers (dextro-rotatory and levorotatory) of PLA present different chemical properties. The levorotatory form (L), called poly-L-Lactic acid (PLLA) is highly hydrophobic and crystallized, with a longer degradation period (a few years approximately), which allows it to act as an inert material. The dextrorotatory form (D) is more amorphous and less

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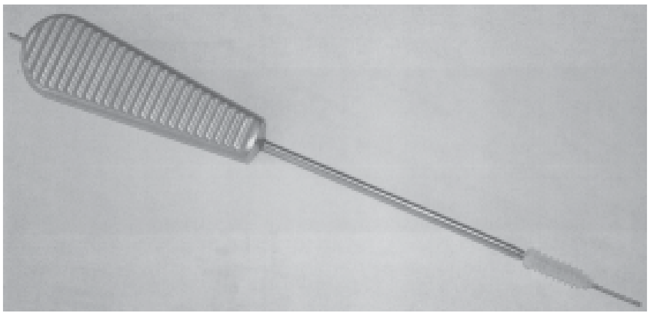

Fig. 2. Bioabsorbable interference screw with central guiding Kirschner wire and cannulated screwdriver

stable, being suitable as a precursor for certain co-polymers [6]. Temperature for transition between malleable and glazed form is 57 degrees Celsius.

The matter of optimal degradation period led to the need of developing co-polymers. By adding D-type isomers during the polymerisation process of L-type isomers, macromolecule chains become wider and cannot be packed together so tight like in the case of PLLA. This leads to attainment of a less crystallized form, with a higher degradation speed.

At present, graft fixation in ACL reconstruction is performed almost exclusively with absorbable interference screws (fig. 2). These are mostly made of PLA, PLLA and PGA. Other osteoconductive materials can be added as well, such as tricalcium phosphate (usually in a 30% ratio). Tricalcium phosphate is found not only on the surface of the screw, but also blended with the plastic material, in order to stimulate osteogenesis and ossification of the remaining space after the implant is absorbed.

Bioabsorbtion and tissue reaction to the implant

The bioabsorbtion process starts with a hydrolytic reaction, which breaks the esteric bonds between macromolecule chains, leading to their fragmentation. Progressively, the macromolecules decrease in size to oligomer and then monomer form. PGA breaks into glycolic acid, which is mostly eliminated through the urine, either directly or after conversion to glycoxylic and oxalic acid [7]. PLA is reduced to its monomer – lactic acid, which, after converting to pyruvic acid is included in the Krebs cycle, in the end resulting carbon dioxide and water, compounds which are eliminated or further on utilized in the organism metabolic processes.

The local enzymatic action of esterase also contributes to the degradation of the bioabsorbable material, by breaking the esteric bonds of macromolecule chains. This reaction, due to the side-products it generates, lowers local *p*H and creates an environment even more suitable for this degradation process to take place. Finally, macrophages and multinucleated giant cells incorporate the remaining macromolecule fragments, resulted after the chemical reactions described above.

The capacity of the interference screw to be bioabsorbed is influenced by many factors. First of all, we must consider the chemical structure of the manufacturing material; the more amorphous its structure is, and the higher its hydrophilic properties, the better it can incorporate a larger quantity of water molecules and pass through a hydrolysis process faster. Other factors influencing the implant absorption speed are related to the materials molecular weight (the larger the molecule, the slower the degrading process), the ratio between different monomers (in the case of co-polymers), molecule stereoisomery. Also, the screw volume and the ratio between its volume and the contact surface with the host tissue, the number of pores and the presence or absence of certain additives (such as tricalcium phosphate) can influence the bioabsorbtion process [8].

The implanatation of these screws determines a local reaction from the host organism, meaning a granulomatous inflammatory response (lymphocyte, plasmatic, endothelial and rare giant cells aggregation). The screw is surrounded by a pseudocapsule, with a thin interior layer (made of approximately 2-3 cellular layers), and an exterior fibrous layer, containing rare spindle cells. Through immunohistochemistry determinations, it was found that type III collagen resides in the interior layer of the pseudocapsule, and type I in the exterior one. Histopathological examination of the tissues surrounding the implant have shown that this “foreign body” type reaction is accompanied by T lymphocyte migration and macrophages which tend to phagocyte all particles resulted from the degradation process which are smaller than 25 micrometers.

This tissue reaction to the implant can be sometimes accompanied by clinical signs as well. A rash-type reaction of the tissue overlying the tibial tunnel can appear especially when we use PGA screws. This rash can lead to liquid accumulation (blistering), which can be proved to communicate with the end of the screw with the occasion of spontaneous or surgical evacuation of the content. In other cases, the inflammatory reaction can extend inside the joint, determining synovitis and effusion (hydarthrosis) [9]. At X-ray examination, more than half of the cases present an osteolytic process surrounding the implant. These phenomena are usually transitory, and heal spontaneously or may need a minimal local surgical debridement. Cases in which the extraction of the implant is necessary are very rare, and this procedure becomes mandatory only if it breaks or gets an infection.

Results and discussions

Primary fixation of the ligament graft in the tunnel represents the main issue of this surgical procedure. This fixation is performed according to the interference principle, meaning that the screw is longitudinally driven between the graft and the wall of the tunnel [10]. A number of studies have shown that average and long-term postoperative results are not significantly different according to the type of screw used (absorbable or non-absorbable) [11]. Also, no significant differences were recorded between cases of ligament reconstruction using patellar tendon graft (bone-tendon-bone) and those using the hamstring technique [12]. Numerous experimental and then clinical studies regarding the optimal length and thickness of the screws were conducted, in order to increase the quality of primary fixation. Increasing the length of the screw (to fill as much of the tunnel as possible) proved to improve fixation quality more than an increase in thickness [13]. In general, in the case of tibial tunnel fixation, the thickness of the screw should be equal to the diameter of the tunnel. For some types of screws, and especially in case of hamstrings graft technique, manufacturers recommend a screw thickness 1 mm larger than the tunnel diameter.

Bioabsorbable interference screws (fig. 3) can be used for tibial and/or femoral fixation of patellar or hamstrings knee tendon grafts in ACL reconstruction in the knee. The screw is cannulated (presents a central tunnel) in all its length, which allows a guided introduction by using a 1.5 mm Kirschner wire (fig. 4). Guiding prevents the screw from leaving the tunnel while being tightened in. The screwdriver used to introduce the screw is also cannulated,

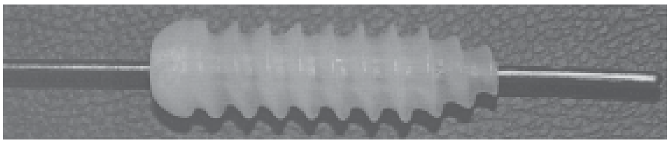

Fig. 3. Bioabsorbable interference screw with central guiding Kirschner wire

and penetrates into the screw in all its length, in order to avoid breakage of the implant during tightening. The inner shape of the screw is usually hexagonal, as this profile provides a good contact between the screw and the screwdriver. Screws are available in different diameters (7 to 11 mm) and lengths (23 to 30 mm).

Until that part of the ligament graft inside the tunnel is not biologically attached to the walls of the tunnel, the interference screw is the only device responsible for maintaining the new ligament in a correct position. This is why, in the first 6 weeks after surgery, only a partial weight bearing of the respective inferior limb is allowed, and passive and active mobilization of the knee must respect certain amplitude limits.

Conclusions

In the last 15 years, the use of bioabsorbable interference screws in ACL reconstruction has increased substantially in our country, too. At present, metallic screws have been completely abandoned from current practice regarding this type of surgical procedure. On the other hand, continuous improvement of the materials, manufacturing technology and implantation tools have allowed the elimination of the majority of disadvantages and complications connected to this type of screws. Cannulated screws allow a precise introduction, using thin Kirshner guide-wires. All length contact between the screw and the screwdriver, through a hexagonal muff, allows control over the tightening force and prevents breaking the implant.

Fig. 4. Bioabsorbable interference screw with central guiding Kirschner wire and cannulated screwdriver

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