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**Tuberoplasty: Minimally invasive osteosynthesis technique for tibial plateau fractures**

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**KEYWORDS**

Tibial plateau fracture; Balloon reduction; PMMA filling; Minimally invasive surgery; Arthroscopy

**Summary**

Fractures of the tibial plateau are in constant progression. They affect an elderly population suffering from a number of comorbidities, but also a young population increasingly practicing high-risk sports and using two-wheeled vehicles. The objective of this study was therefore to propose a new technique for the treatment of this type of fracture. There are a variety of classical pitfalls of conservative treatment such as defective reduction resulting in early osteoarthritis and alignment defects. Conventional treatments lead to joint stiffness and amputee of the quadriiceps, caused by the open technique and late loading. We propose an osteosynthesis technique for tibial plateau fractures with minimally invasive surgery. A minimally invasive technique would be more appropriate to remedy all of the surgical drawbacks resulting from current practices. The surgical technique that we propose uses a balloon allowing progressive and total reduction, associated with percutaneous screw fixation and filling with polymethylmethacrylate (PMMA) cement. The advantages are optimal reduction, minimal devascularization, soft tissues kept intact, as well as early loading and mobilization. This simple technique seems to be a good alternative to conventional treatment. The most comminuted fractures as well as the most posterior compressions can be treated, while causing the least impairment possible. Arthroscopy can be used to verify fracture reduction and cement leakage. At the same time, it can be used to assess the associated meniscal lesions and to repair them if necessary.

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Introduction

The Programme de médicalisation des systèmes d’information (PMSI) data (http://www.atih.sante.fr) recorded 4055 external tibial plateau fractures in 2010 in France. These include fractures of the cleavage-compression type in the Duparc and Ficat classification [1] (corresponding to Schatzker type 2) accounting for 55% [2]. Their growing number can be explained by several factors: democratization of high-risk sports, the widespread use of two-wheeled vehicles [3], an aging population with high comorbidity factors [4], etc.

Reduction, osteosynthesis, and treatment of the lesions associated with these fractures are recommended. The classical open osteosynthesis techniques or those using a bone tamp present several problems [3]: a risk of infection, bone [5] and skin devascularization [6], deferred weight-bearing, and scarring problems. In addition, conventional surgery prohibits making the diagnosis and treating the associated lesions simultaneously, contrary to arthroscopy [7].

We propose a new minimally invasive technique for external tibial plateau fractures involving compression and cleavage (Schatzker 2) using a balloon and two percutaneous fixation screws associated with polymethylmethacrylate (PMMA) cement filling. Arthroscopy makes it possible to visualize the associated lesions and any cement leakage as well as to verify the fracture reduction. This new therapeutic approach was elaborated and perfected using trials on cadavers before being clinically validated.

Patients and method

Patient type

The diagnosis of an external tibial plateau fracture is made on AP and lateral X-rays, according to the current guidelines. If these images confirm the fracture, a secondary CT image is taken. The CT scan is used to localize the injury and assess the topography of the fracture, classify it, and quantify it [8]. This new technique is recommended for fractures with cleavage and compression or only compression, with no regard to age, sex, bone density, or location (anterior, median, and posterior). It can be applied in all circumstances of associated soft tissue lesions.

Material and installation

The material required for this new technique includes: a 20-cc Kyphon® balloon from Medtronic® for fracture reduction, two cannulated fixation screws for osteosynthesis, PMMA cement to fill the cavity, and an image intensifier to verify the reduction and implant position. An arthroscopy column can be used to diagnose and treat the associated lesions and check intra-articular reduction.

Two installations are recommended. In cases of a fracture with cleavage the most dominant component compared to compression, the patient is installed on an orthopaedic table to produce a ligamento taxis effect. In the contrary cases, in which compression is predominant, installing the patient on a standard table is recommended because the patient is easy to install and arthroscopy can be used (Fig. 1).

Approach

The surgery begins with a conventional arthroscopy of the knee if necessary, which allows the surgeon to assess the associated lesions and treat them. This surgical time can also be used to wash the hemarthrosis. Using arthroscopy complicates the operation and increases the surgical time and is mainly recommended for young subjects in whom meniscal repair is possible [9]. The technique is minimally invasive and consequently preoperative planning of the entry point is crucial.

Entry point

After the AP X-ray examination, a vertical axis passing through the middle of the compressed tibial plateau must be defined. When in doubt, it is wiser to place this vertical axis on the lateral side so that the lateral metaphyseal cortex can be used as support when inflating the balloon. The entry point is located on this vertical axis 0.5 cm below the maximum compression (Fig. 2).

Figure 1 Photo of patient installation.

Figure 2 Diagram of entry point.
An incision is made in the skin with the cold blade scalpel down to the bone 1 cm from the entry point. A corticotomy is done with a 4-mm drill to insert the One-Step™ OsteoIntroducer™ working cannula. Then, using the lateral X-ray, the cannula with the a traumatic foam end is inserted so that its extremity reaches the posterior cortex. Once the tunnel has been made, the cannula plug is replaced with the balloon. The working cannula is then removed so that the balloon appears in the previously formed tunnel. The amount of cannula withdrawn should approximately match the length of the balloon used. To verify that the balloon will come out easily, the two radiopaque markers located on both sides of the balloon must be visible on the lateral radioscopic guidance system (Fig. 3). Assisted with lateral radioscopic guidance, the balloon is placed in the sagittal plane below the compression. In this phase, one should prefer placing the balloon in a posterior position so that it is against the tibia’s cortical bone. In the contrary case, if the balloon is placed in the middle of the tibia in the sagittal plane, it will only be in contact with cancellous bone, which creates a risk of problems in the effective reduction of the fracture.

In case of cleavage, a bone-holding forceps is placed between the external and internal condyle to maintain the two fragments of the plateau. This positioning is only possible after having positioned the balloon because the metallic forceps could diffract the X-rays of the image intensifier needed for the preceding step.

**Reduction**

The balloon is inflated with a contrast agent, without going beyond the manufacturer’s norm of 350 PSI, slowly and progressively. The balloon is used to reduce the compressions, even the most comminuted. As in vertebral kyphoplasty, the balloon is pressurized at first at 200 PSI, the none must wait until the pressure lowers. This means that the balloon is expanding (inertia of the bone masses) and that the plateau is redirected toward its anatomical position. Once the pressure has lowered (100 PSI), contrast fluid must be reinjected into the balloon so as to continue reducing the fracture. This operation can be carried out several times until total reduction is achieved, being careful not to exceed the balloon’s capacity (20 cc) (Fig. 4). Nevertheless, if a reduction defect persists, the balloon can be deflated, repositioned, and reinflated to reduce the persistent compression. In all cases, reduction is achieved under radioscopic and/or arthroscopic guidance.

Before deflating the balloon, it is necessary to tighten the forceps. If the space between the plateau and the balloon allows it, the guidewires of the cannulated screws are positioned before the balloon is deflated. They should be located just below the compressed tibial plateau (between the balloon and the plate) in a bicortical fashion. This makes it possible to support the reduction and thus avoid possible loss of correction when the balloon is deflated. The
guidewires should be positioned with extreme caution so as not to puncture the balloon. Using lateral radioscopic guidance is highly recommended. When the surgeon is satisfied with the reduction, the balloon can be withdrawn.

**Osteosynthesis**

The synthesis initiated by the guidewires will be terminated by implanting cannulated screws with rings [10]. They will be tightened, under AP radioscopic guidance, so as to keep the physiological external tibial condyle offset and to be sure that they are bicortical, thus providing better stability. The cannulated screws should be located immediately below the compressed tibial plateau. Positioning the screws before injecting the cement makes it possible to tighten the parts of the tibial plateau and thus to prevent cement leakage (Fig. 5).

**Filling**

The cavity formed by the balloon is secured by the compression of the cancellous bone [11] and thus allows use of PMMA cement filler, which has better mechanical stability [12]. The cement is prepared according to the manufacturer’s recommendations during the screw positioning phase. This prior preparation makes it possible to minimize the surgical time. The mean volume of cement injected is 3.5 cc, corresponding to the quantity of liquid used for inserting the balloon. Bone Fillers® are then used to fill the new cavity (Fig. 6). Absence of leakage is verified using the radioscopic device, AP and lateral and/or intra-articular with arthroscopy. If there is leakage, the PMMA cement can be removed via an endoscopic approach. The end of the intervention is marked by the removal of the bone-holding forceps, the arthroscope, and suturing the three 1-cm incisions. The postoperative images can then be taken (Fig. 7).

**Discussion**

Tibial plateau fractures account for 1.2% of all fractures [13]. More than half of them are Schatzker 2. The incidence of this type of fracture is probably underestimated. Recent imaging articles [14], most often demonstrate a cleavage...
component and very little pure compression, which was difficult to assess in earlier times on plain X-rays.

The treatment principle for these fractures is to obtain reduction as close as possible to the patient’s anatomy and effective stabilization allowing early activity resumption. To meet these objectives, we developed a minimally invasive surgical technique for Schatzker 2 fractures.

Following current guidelines, we systematically performed a CT to obtain a three-dimensional analysis of the fracture [15]. This CT planning allowed us to better evaluate the fracture and define the AP entry point for the balloon, its lateral positioning, and determine the screw positions.

Use of arthroscopy is an additional benefit in checking the reduction [16] and in treating meniscal lesions. It should be noted that if lateral tibial plateau compression is greater than 14 mm and/or the inter-fragmentary gap greater than 10 mm, there is a significant association with a meniscal lesion [17].

In our experience, this minimally invasive approach presents a number of advantages compared to technical techniques. The absence of muscular damage reduces postoperative pain and facilitates rehabilitation. The anterior point of introduction under the fracture site is made by an avascular window [5], limiting risks of infection and scarring problems and preserving the blood supply to the periostium and thus bone union (which is not the case for the technique using bone tamp). The balloon allows access to the posterior compressions while eliminating the neurological and vascular risks of a conventional approach.

With the entry point located very close to the compression, we never needed to use Kirchner wires to support the balloon, contrary to what has been described in the literature [18]. We did not find introducing the balloon through a lateral approach in the posterior compression [19] to be well adapted, given the risk of pushing back the fragment. Moreover, this technique most often requires use of several balloons to cover the entire compression area.

The present technique uses the balloon in the anteroposterior direction, which thus makes it possible to adapt to the convex shape of the external plateau and reconstruct its anatomy more accurately. We were thus able to treat all of the compressions, no matter what topography they presented, with a single balloon. This balloon achieves gentle and progressive reduction of the fractured tibial segment and its shape reduces highly comminuted fractures, which is also very delicate when using graft removal. Moreover, the volume of the cavity formed by the balloon, by compressing the cancellous bone, is small compared to the technique using the bone tamp, leaving a smaller area to fill.

The osteosynthesis, which was also percutaneous, was performed using two bicortical percutaneous screws. The choice of screw diameter was 3.5 mm, in accordance with the Patil et al. article in The Knee [20]. This choice of osteosynthesis technique allowed rapid weight-bearing on the tibia and thus avoided joint stiffening [21]. In cases of single or multiple cleavage, it is wise to prefer using a percutaneous plate.

Filling the residual newly formed cavity with PMMA cement provides stability in direct loading and therefore reduces postoperative immobilization. In addition, the Doht et al. article [22] showed the superiority of the cement — screw assembly compared to screws alone. PMMA cement has the advantage of providing greater mechanical stability. It is a tried and true method in orthopaedic surgery, notably in vertebral kyphoplasty. The use of bone graft material to fill the cavity requires a longer time to weight-bearing, which generates joint and muscle problems. The ideal would be to use resorbable cement, osteoinductive or osteoconductive biomaterials, with the same mechanical characteristics as PMMA cement. This would allow the material to be removed, leaving no inert body 1.5 years after the fracture.

Use of the balloon forms a cavity that compresses the cancellous bone around the cavity. This becomes a stabilized cavity that provides thermal protection and avoids leakage [11]. The absence of cement leakage prevents proliferation of chondrocytes, which can warrant use of an arthroscope to ensure absence of leakage in cases requiring cement removal.

Conclusion

This new minimally invasive tuberoplasty technique is a good alternative to the conventional technique using a bone tamp in the treatment of tibial plateau fractures. It provides anatomical reduction of the fracture in a gentle and progressive manner, minimally aggressive osteosynthesis, and mechanical stability allowing early rehabilitation and rapid weight-bearing. Arthroscopy combined with this technique can also evaluate any associated lesions.

This new technique developed on cadavers shows the relevance of tuberoplasty. It should be implemented on patients who have consented to the procedure. In addition, a biomechanical study is planned to quantify the admissible mechanical loads for rapid weight-bearing.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.
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