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Research Article,

Use of Carbon Plates for the Treatment of Supracondylar Femoral Fractures: Preliminary Experience

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Abstract:

Introduction

Distal femur fractures in adults have an estimated annual incidence of 6% of all femur fracture. Choice of the type of fixation depends on the characteristics of the fracture and the general condition of the fractures carbon fiber reinforced—polyetheretherketone (cfrpeek) offer several potential benefits when compared with metal alloy implants, including a modulus of elasticity approaching cortical bone and fatigue strengths greater than most metals.

Material and methods

We retrospectively identified treat 17 patients, treated with minimally invasive plate osteosynthesis (mipo) with carbon plates (piccolo composite ®). The patients were evaluated with clinical and radiographic follow-up at 1 month, 3 month, 6 month e 1 year. The clinical evaluation was performed using knee society score (kss) and the CAS score.

Results

Clinically 15 of 17 patients examined healed (88,2 %), 1 patient (5,8 %)went to delay of consolidation healed in 11 month), 1 (5,8 %) patients went to non-union and we perform a revision arthroplasty. The mean healing time was 92,88 days (st. Dev 28,63, min. 56 d – max 140). The mean cas score at 1 year was 4,47 (st. Dev 1,46, min 2 – max 6). The mean kss at 1 year was 73, 11

Discussion

Titanium has good osseointegrative properties and an elastic modulus more similar to bone. Carbon plates with a stiffness closer to the 159 modulus of elasticity of bone, and exhibiting better fatigue properties, could be a good alternative to existing metallic plates. Our group of patients showed average healing time of about three months, but the formation of callus is evident as early as 1 month after surgery. For this reason a partial weight bearing was early allowed in 15 patients. Which guarantees a recovery of daily activities from 5 months after surgery, reducing the risk of mortality.

Conclusion

The new carbon plates guarantee the possibility of performing a more elastic synthesis that is closer to the biological characteristics of the bone.

Keywords: Carbon plates, supracondylar femur fractures.

Introduction:

The management of distal femur fractures is considered challenging and technically demanding, because of the complexity of the regional anatomy and the multifragmentary pattern of injury. Distal femur fractures in adults have an estimated annual incidence of 6% of all femur fracture [1], and occur in a bimodal distribution. The first peak refers to young male below 40 years of age and usually occurs after high-energy trauma, whereas

the second peak occurs in elderly women, with osteoporotic bone, as a result of low-energy trauma and falls. [2], [3]. In elderly patients, the presence of osteoporosis, metaphyseal comminution and poor soft-tissue conditions have resulted in less predictable outcomes. Furthermore a high rate of complications such as significant venous thromboembolism, cardiac complications, respiratory complications, acute kidney injury, gastrointestinal bleed requiring transfusion or intervention, and urinary tract infection shold be considerated [4]. Larsen et [5]al showed also an high rate of mortality in patients with this type of fracture: the overall one-year mortality rate was 21% for non-periprosthetic distal femur fractures and was elevated to 35% in patients older than 60 years.

Patients presenting with a periprosthetic fracture showed a one-year mortality rate of 15% [5]. The AO/ OTA system is most universally used for fracture classification.4 Fracture patterns include type A (extraarticular), type B (partial articular/unicondylar), and type C (complete articular/ bicondylar). Further classification into subtypes 1, 2, and 3 indicates the progressively increasing degree of comminution[6]. Surgical treatment is generally indicated, non-surgical treatment is reserved for patient with both high comorbidity and not ambulatory before the fractures [7]. Butt showed clear benefit from surgical treatment with internal fixation of distal fractures of the femur compared with non operative treatment[8]. A good healing depends on an anatomic reduction of the articular surface, and restoring the length rotation and alignment.[9]. According Zehntner et al. [10]satisfactory functional result depend on angulation differences. Angulation difference of less than or equal 5 degrees in any plane ensure good functional results. Patients with fracture that heal with more than 15 degrees of valgus or any degree of varus may develop secondary arthritis[10]. Choice of the type of fixation depends on the characteristics of the fracture and the general condition of the fractures. [11]. Carbon fiber reinforced—polyetheretherketone (CFRPEEK) is a composite material made of layers of carbon fiber sheets oriented in varying directions imbedded in a polymer matrix. CFR plates offer several potential benefits when compared with metal alloy implants, including a modulus of elasticity approaching cortical bone and fatigue strengths greater than most metals. [12] Aims of our study is to retrospectively evaluate the outcome of a distal femur fracture treated by PEEK plate fixation with regards to union, complication, and functional recovery of patients

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Material and methods:

This retrospective study was approved by the Ethics Committee of the hospital of Piacenza and performed in accordance with the Helsinki Declaration. All patients agreed to participate and provided written informed consent prior to treatment. The inclusion criteria were: adult patients affected by supracondylar femur fracture, treated with carbon plates. Exclusion criteria was pediatric patients, and adult patients treated with other type of fixation. We retrospectively identified treat 17 patients. Patients was treated between January 2016 and December 2018 for distal femur fractures. Mean patients age was 74.4 years (range 56-89). There were 6 male (35.29%), 11 female (64.7%). We classify the fractures according AO classification. We identified 4 type A 23,52%, 8 type B 47.05%, 5 type C 29,41%. All the surgical operations was performed by senior Author. The fractures were treated with minimally invasive plate osteosynthesis (MIPO) with carbon plates (Piccolo Composite ®). The plates made with carbon fiber arranged both longitudinally and transversely, and immersed in a polymeric matrix, called PEEK = polyetheretherketone. Carbon fibers are present at 70%, while the remaining 30% is PEEK. The Distal Femur plates are anatomically shaped with screw holes accommodate both locking and non-locking screws. Poly-Axial locking screws give freedom of insertion and directionality according to the needs (about 30 ° conical). The screws are in titanium Ti 6Al-4V.A radiopaque tantalum marker positioned along the entire profile of the plate allows optimal visualization under fluoroscopy The patients were evaluated with clinical and radiographic follow-up at 1 month, 3 month, 6 month e 1 year. The clinical evaluation was performed using knee society score (KSS) [13] and the CAS score. The cas score evaluates the independence of the patient through the performance of 3 activities: 1) Stand up and lie down in bed, 2) sit down and get up from the chair, 3) ability to walk. Each activity is evaluated from 0 to 2 points, for a maximum score of 6 which indicates the total independence of the patient[14]

The radiographic controls were performed to assess the progress of the healing and any defects

of consolidation, delay bone healing or non-union.

Results:

Clinically 15 of 17 patients examined healed (88,2 %), 1 patient (5,8 %)went to delay of consolidation healed in 11 month), 1 (5,8 %) patients went to non-union and we perform a revision arthroplasty.

The mean healing time was 92,88 days (st. Dev 28,63, min. 56 d – max 140). The mean CAS score at 1 year was 4,47 (st. Dev 1,46, min 2 – max 6).

The mean KSS at 1 year was 73,11 (st. Dev 14,87, min 45 – max 98); 69,3 for type C fracures, 74,2 for type B fractures, 79,8 for type A fractures.

At 1 years of follow up no defects of consolidation were reported at radiographic control for all patients. (FIG 1)

Partial weight bearing was allowed at 8 weeks in 15 patients.

Figure1A Figure1B

73 y.o female patient, AO 33 B3 fracture (a) treated with carbon plate and titanium screw. 3 months follow-up (b)

Discussion:

The choice of the type of materials used for osteosynthesisis plays a key role in the healing process. Stainless steel and cobalt chrome metal alloys are characterized by corrosion resistance, strength, ease of processing, low costs and adaptability to the patient's anatomy.

Titanium has good osseointegrative properties and an elastic modulus more similar to bone. However, the disadvantages of metal implants are different: low resistance to stress, discrepancy with the modulus of bone elasticity, possibility of debris formation, cold fusion between screws with angular stability and titanium plates, corrosion, and finally the radiopacity of the implants precludes a correct visualization of the fracture outbreak, healing, possible tumour or infectious progressions [15]. For these reasons, the use of carbon has become increasingly popular in recent years.

Biomechanical properties

Several studies have been performed to evaluate biomechanical properties of carbon[16]–[18].

Plates with low axial rigidity can reduce the negative effect of stress shielding, that is the osteopenia induced by the cancellation of the load forces present on the bone, following the implantation of highly rigid plates.[17]

The carbon plates have, instead an elastic modulus more similar to the bone one (7-25 Gpa), they allow a greater distribution of the loads in comparison to the titanium and steel plates that have higher elasticity modules, respectively 110 Gpa and 220 Gpa [17]. This guarantees a greater mechanical stimulus with consequent formation of hypertrophic callus[19] Further studies performed on carbon plates [16] showed a "fatigue life" of about 1 million cycles at a 60% load. Considering that a patient takes one-step per second for several hours a day, it could be estimated approximately that him performs 1 million cycles per year. That is enough considering that no plates are designed to withstand more than 1 million cycles. The stiffness of the material remains almost unchanged during all the cycles. This is fundamental not only as regards the duration of the implant but also because the loss of mechanical properties could be an indication of a process of flaking of the material with the possible production of debris that can induce an immunological response.

The combination of Polyacrylonitrile (PAN) with carbon fiber (PAN-CF) created a material that accelerate the wound healing. PAN-CF work like a scaffold that promote fibroblast growth and migration, leading to up-regulation of fibronectin and type I collagen, which was theorized to have allowed for accelerated wound healing and closure. [20] Moreover in the literature no case of allergic reaction to CF and hypersensitivity have been showed[20] Steinberg[21] et al tested carbon plates and and titanium screw, and compared the results to titanium devices, particularly the interconnected area and debris. The plates were visually inspected and assessed with the aid of an optical microscope The results showed a significant difference between both collected debris filters, thus indicating that the CF-PEEK had a lower debris weight than the titanium control.[21]

According to the literature [22], [23] in cases where CFRPEEK and similar composite materials

were tested in vivo in animals, the animal response was similar to that induced by UHMWPE. Especially, in cases of CFR-PEEK (and similar composite materials) implants retrieved from patients after implantation, there was a low number of particles in the patients tissue. In addition, in general, titanium is regarded as electrochemically compatible with carbon and resists galvanic corrosion. It should also be noted that the titanium alloy screws are anodized, thus making them more inert.

According Mitchell [12] the treatment of distal femur fractures, CFR-PEEK plate is associated to lower incidence of non-unions and no implant failures compared to stainless steel .Carbon plates with a stiffness closer to the 159 modulus of elasticity of bone, and exhibiting better fatigue properties, could be a good alternative to existing metallic plates. Our results are comparable with those described in literature [24]–[26]. Our group of patients showed average healing time of about three months, but the formation of callus is evident as early as 1 month after surgery. For this reason a partial weight bearing was early allowed in 15 patients. Which guarantees a recovery of daily activities from 5 months after surgery, reducing the risk of mortality.

Limits of this type of plates

One of the limits of this type of plates is the impossibility to incorporate cables at the implant to improve the fixation and to help the reduction of the fractures. Small holes in the plate's body could be useful to integrate the cable.

Limits of our study

The limits of our study are a small cohort of patients, and a mean follow-up of 1 year that is too short to evaluate the duration of this type of fixation.

Conclusion:

The new carbon plates guarantee the possibility of performing a more elastic synthesis that is closer to the biological characteristics of the bone, which translates into faster healing and the possibility of granting an early load that is essential in elderly patients.

Declarations of interest: none

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