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The role of reinforced carbon fiber plates in supracondylar femoral fractures

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Summary

One of the surgical options for the supracondylar femoral fractures is plating. These fractures are often unstable because of many factors depending on the type of fracture (medial wall often involved) and quality of bone (osteoporosis).
Supracondylar lateral plates, even if provided by long plates and good distribution of screws, may fail because of high mechanical stress. In fact, in the literature a non-union rate 21% of is described.
PEEK materials are already used regularly in pathological fractures where better mechanical properties are required where the callogenesis is often slow and uncomplete because of pathological healing process.
Since 2016, the authors used these better mechanical properties (biocompatibility, resistance and elasticity) of PEEK plates in selected trauma cases in the supracondylar femoral site.
Among the few cases successfully treated with lateral PEEK plate, the authors report one peculiar case with 3 years of follow-up highlighting the good properties of reinforced carbon fibers.

Key words: supracondylar, plate, PEEK

Case report

A 68-year-old male presented with septic arthroplasty mobilization (MRSA) implanted 10 years before (Fig. 1A). He was treated in 2017 with arthroplasty removal and antibiotic spacer. During this surgery the distal femoral shaft reported an intraoperative fracture. This was provisionally treated with a temporary metallic cerclage (Fig. 1B).
After 7 days the patient underwent ORIF surgery with a lateral supracondylar PEEK plate using a lateral distal approach: the plate was long enough to stabilize the fracture but intentionally not too long to avoid the proximal femoral canal where the antibiotic spacer was left to manage the infected canal (Fig. 1C).
The wound healed within 20 days with no complications. Weight-bearing was allowed after 40 days. In fact, the proximal K-wire holding the antibiotic spacer broke with no complications, while the PEEK plate presented no mobilization (Fig. 1D).
After 6 months as inflammatory markers decreased, the patient underwent a new operation of spacer removal and arthroplasty revision (removing only the 3 proximal screws of the plate).
No septic complication occurred, weight bearing was allowed soon after the operation, and the patient was followed up monthly in the outpatient clinic.

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Conflict of interest
The authors have no conflict of interest to declare. Authors have seen and agree with the contents of the manuscript and there is no financial interest to report. We certify that the submission is original work and is not under review at any other publication.

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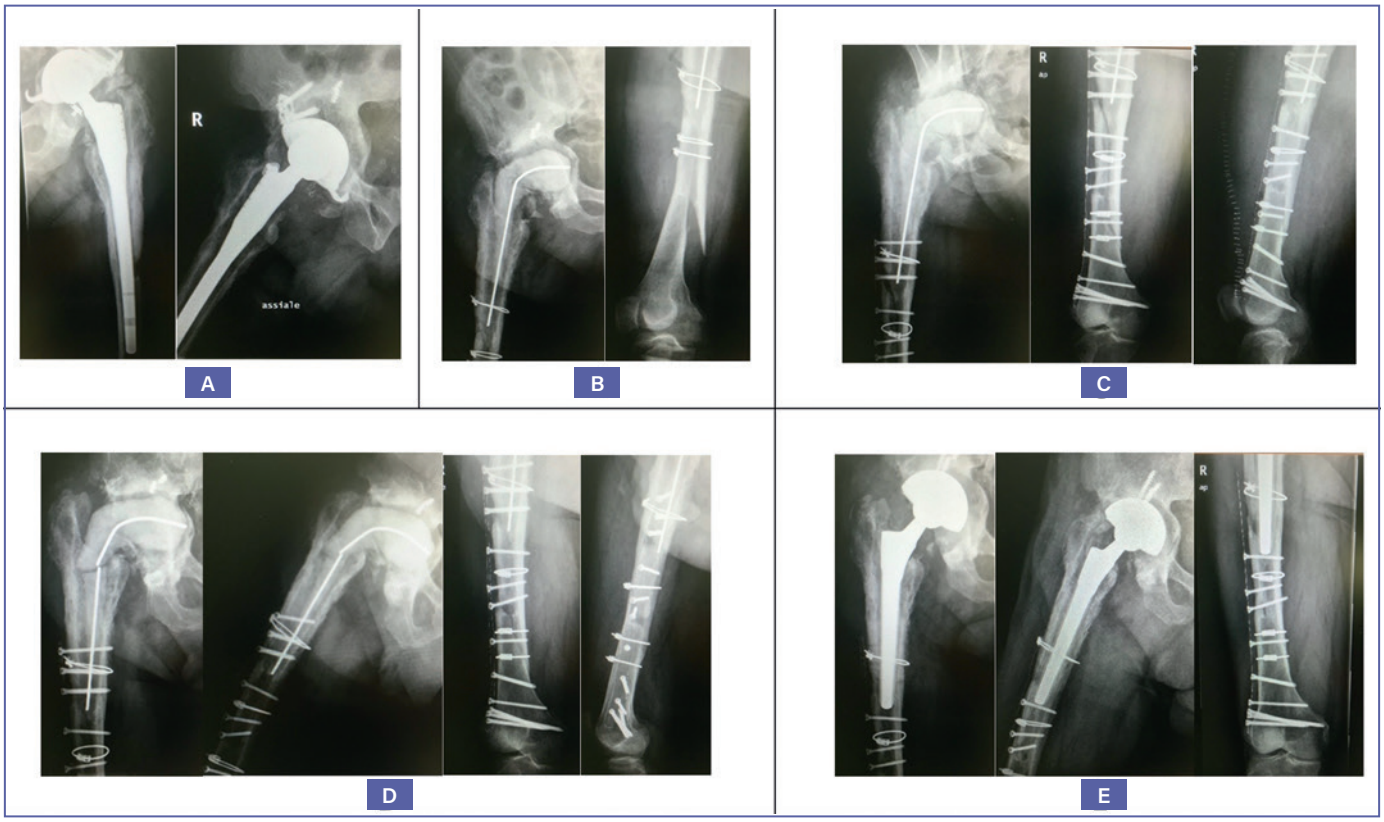

Figure 1. A) Arthroplasty septic mobilization in 2017; B) Iatrogenic supracondylar femoral fracture occurred during arthroplasty removal and treated with antibiotic spacer and provisional cerclage; C) PEEK plate stabilizing the supracondylar femoral fracture after 7 days; D) 40 days f-up with weigh bear allowed: antibiotic K-wire broken while PEEK plate resists; E) 3 years f-up after arthroplasty revision (2021) was done 6 months after inflammatory markers decreased removing the antibiotic spacer.

X-rays at 3 years (2021) follow-up show the arthroplasty and PEEK plate in a good position (Fig. 1E). The patient walks with no pain or limping and had good restoration of everyday life.

Discussion

Supracondylar femoral fractures are relatively common and are associated with high mortality and morbidity. The surgical treatment of this fracture is stable osteosynthesis using retrograde nails or supracondylar plates. In this second option, the surgeons have to reach an implant that is not too rigid and not too elastic (non-union or implant failure) needing revision surgery (Fig. 2).

ORIF with titanium lateral plate is a solid option in supracondylar femoral region in traumatology. However, AO trauma describes some strict rules to decrease any option of implant failure and non-union using long plates and spreading screws along the plate.

Fracture comminution in high energy trauma in young patients and low-energy injuries in elderly ones where bone quality is poor may reduce the level of stability at the distal segment even when all trauma rules are well respected. This result places additional, dangerous mechanical stress on the lateral plate. In fact, in recent years, initial success rates have given way to more concerning outcomes with reported nonunion rates with implant failure as high as 17-21%, with reports of decreased callus formation, problems with healing of up to 32%, and other complications [1].

An additional medial support is described in literature in order to increase the mechanical stability of the lateral titanium plate: another titanium plate by a medial surgical approach or a bone strut in an acute situation [2].

However, a double plating scenario has been related to knee contractures, and damage to surgical bone and soft tissue due to the additional medial approach, blood loss, and increased surgical time.

Carbon fiber materials such as nails and plates are well-known in the literature in the last decade for their mechanical prop-

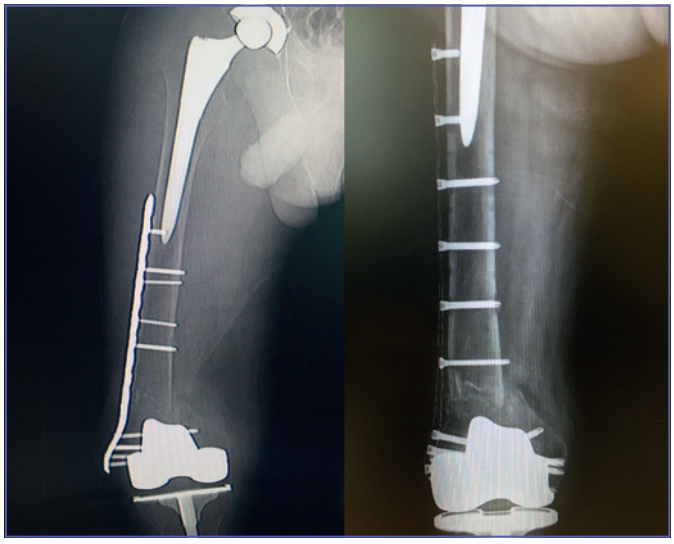

Figure 2. Supracondylar femoral fracture treated with lateral titanium plate failed at 2 months revised with a PEEK lateral plate.

erties [3-5]: they better resist to stress tests and show an elastic module more similar to that of normal cortical bone.
Normal titanium implants fail after 50,000-100,000 physiological weigh cycles, while the CF-PEEK can tolerate more than 1,000,000 cycles [5].
The elastic module similar to normal bone allows a more homogeneous distribution of forces to the plate-bone interface during weight-bearing, thus avoiding stress-shielding and stimulating an early bone callus formation [4].
One study has compared CF-PEEK plates to stainless-steel plates showing a reduced incidence of non-union (9 *versus* 36%) and reduced implant failure (0 *versus* 18%) when CF-PEEK plates are used.
Carbon is a material whose origin is more compatible to bone than metals.
Studies on rats have showed a better and more uniform osteoinductive properties along the implant-bone interface compared to titanium. This leads to better osteointegration derived from intrinsic electric properties of carbon by stimulating tissue formation [4].
No corrosion and degradation of carbon fibers has been seen in lab tests: this, added to the less debris production, protects the fracture site from a negative inflammatory response that could lead to implant failure [3].
These characteristics make these implants suitable in pathological fractures where the fracture site has an abnormal metabolism leading to a slow process of callus formation or sometimes to the absence of callus formation in an advanced metastatic cancer scenario. These conditions require implants with high mechanical properties in term of resistance.
In pathological fractures, PEEK materials are also used because of their radio-transparent property, allowing the oncologist to have a better view ofcancer evolution on bone without radiolucent interference at postoperative x-rays as in titanium implants.
Another advantage is the use of self-tapping and self-locking titanium screws in the carbon plates avoiding cold fusion complications. This condition is well described in the literature in titanium implants complicating any possible implant removal.
The case reported had an intraoperative complication with an iatrogenic fracture during a septic stem hip arthroplasty.
This fracture, provisionally treated with a metal cerclage, needed a stable osteosynthesis in the anatomical region (femoral shaft) where a bone spacer was implanted.
The choice to perform an ORIF using a lateral CF-PEEK supracondylar plate toreduce and stabilize the fracture with a plate whose material was as long as possible and biocompatible (to decrease the risk of recurrent infection), as long as possible resistant (to use a plate as short as possible to avoid the infected proximal femoral region), as long as elastic like the normal bone (to promote callus formation and leaving the patient free to move the hip without any implant failure).
The post-operative and follow-up pictures show that the plate was enough stable to tolerate patient weight bearing (picture shows the broken K-wire in the antibiotic spacer), elastic enough to promote callus formation healing of the fracture and biocompatible to avoid disturbing the proximal MRSA infection to heal.
The case showed good success at 3 years follow-up in an extreme indication, and further demonstrates the potential properties of CF-PEEK plates and materials.
CF-PEEK plates have shown good biocompatible and mechanical properties in lab tests and for this reason are a valid option not only in pathological fractures, but also in ordinary traumatology cases especially in anatomical site like supracondylar distal femur where the level of fracture instability is often high (osteoporosis and medial wall fragmentation), and where titanium implants have previously failed (revision of early implant failure too rigid) or in selected extreme cases like the one reported herein. In these cases, carbon fibers might represent a more biocompatible, resistant, and compliant implant to the bone. Even if our experience is still limited in term of numbers pf patients and longer follow-up, we believe that these implants can help to reduce ORIF failures and non-union rates in supracondylar distal femoral trauma.

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