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CHEF-K, a hybrid technique for early recovery in complex tibial plateau fractures: a case report

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Summary

The treatment of complex tibial plateau fractures is a challenge for even experienced orthopedic surgeons. While it is established that type and timing of surgical treatment depends on the involvement of soft tissues, there is no agreement in the literature about post-surgical weight-bearing on the operated limb: it ranges from a total ban to a partial concession of 6 to 12 weeks. Weight-bearing modulation can be difficult in physically challenged or frail patients such as the elderly, with a real risk of hypokinesis, bedridden and related complications. To allow the early treatment of these fractures and immediate weight-bearing, we connected a circular external fixator (CEF) to a hinged knee external fixator (HEF) with specific axial load resistance characteristics. This hybrid technique, which we have called CHEF-K (Circular and Hinged External Knee Fixation), maintains and combines the mechanical characteristics of both devices. In selected cases we early stabilized the fracture in a minimally-invasive way associated with CEF, then protecting the osteosynthesis with HEF which bypassed the fracture during loading while also allowing movement of the knee. In the first case described herein, a 78-year-old woman showed rapid functional recovery, being able to walk without aids after 4 weeks.

Key words: tibial plateau fractures, hinged external fixator, elderly, fracture, recovery, postoperative weight-bearing

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Introduction

Complex tibial plateau fractures usually result from high-energy trauma with significant soft tissue involvement. Lately, these fractures have increased even in elderly people with complex injury patterns resulting from low-energy trauma related to osteoporosis and skin fragility.
Universally accepted principles of surgical treatment are:

- anatomical and stable reduction of the articular surface;
- restoration of the anatomical tibial axis;
- respect of soft tissues;
- early mobilization after surgery.

These objectives can be achieved through different operating techniques. Open reduction internal fixation (ORIF) is the gold standard even if it requires soft tissue dissection with an increased risk of skin complications. In significant edema or skin

distress, two-stage fracture management is frequently preferred, using temporary external fixation (EF) in the first step. EF, otherwise, finds its elective indication in open fractures or serious integument damage. Minimally-invasive techniques have shown good results with a low risk of skin complications. Among these, Percutaneus reduction internal fixation (PRIF) combined with EF has already described [1,2]. Regardless of the treatment chosen, however, there is no unanimous consensus on when to allow weight-bearing of the injured limb: it varies from an absolute ban to partial weightbearing for a minimum of 6-8 weeks up to 10-12 weeks. Even in a recent literature review [3] the granting of weight-bearing depends on the complexity of the fracture and the synthesis method used. This restriction delays functional recovery in young patients and can be very difficult to manage in subjects with temporary motor disability such as in concomitant fractures of the arms or contralateral limb, in subjects with a high body mass index or in "fragile" people such as the elderly. In these individuals, frequently affected by sarcopenia, restriction of the load can lead to further falls or to bedridden with related complications. Based on these reflections and the rationale of fast-track protocols in femoral neck fractures in the elderly, we looked for a system that allowed early fracture fixation and immediate weightbearing, without specific restrictions.

We took inspiration from the well-known use of hinges to bridge the joint in Ilizarov's systems used in articular femur and tibia fractures [4,5], and from the concepts expressed by Volkow and Oganesian on the hinged fixators [6]. Furthermore, our team had already gained good experience in the use of the HEF of knee developed by Marcacci [7] in selected cases of knee dislocation or fracture-dislocation and in some complex tibial plateau fractures treated with ORIF. We imagined combining this system with the CEF obtaining a hybrid device that allowed to achieve definitive fracture stabilization and immediate postoperative loading "as tolerated", i.e. protected by aids without specific restrictions during the first 6-8 weeks, considered as "critical" by most studies [8]. We called this technique CHEF-K (circular and hinged external fixation of knee).

Description

A 78-year-old woman was taken to the emergency room for road polytrauma and referred pain to left hemithorax and left knee edema and swollen joint without major soft tissue damage or vascular-nervous deficits; X-rays showed comminuted fracture of the left proximal tibia, Schatzker Type V (AO/OTA 41C3) and multiple rib fractures with pneumothorax,

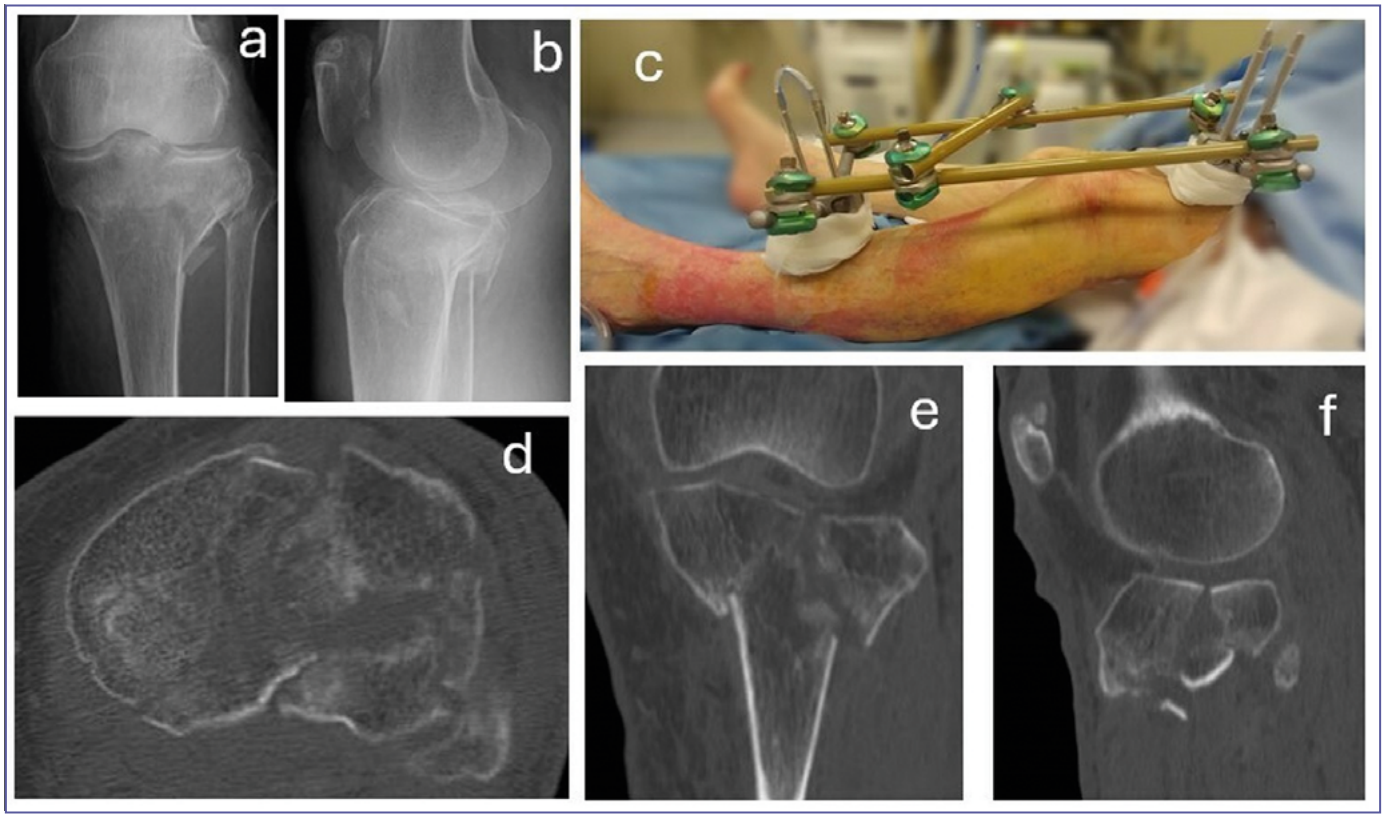

Figure 1. X-rays showed comminuted fracture of the left proximal tibia, Schatzker Type V (A,B). Damage control orthopedics was performed with temporary knee bridging EF (C) following the flow chart "spam, scan, (D-F) plan".

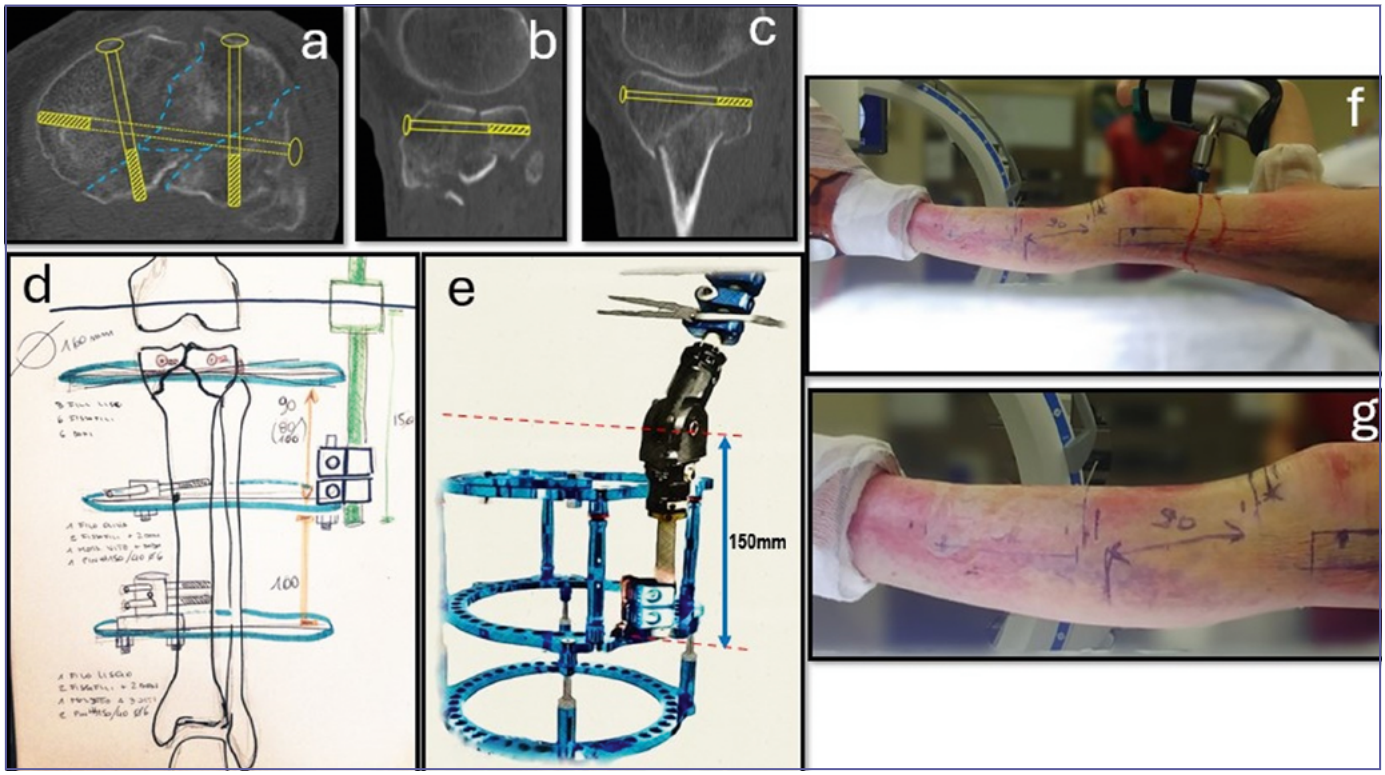

Figure 2. CT study was fundamental: 1) to plan the synthesis with cannulated screws in compression the articular fracture that would allow the transformation of the type C into type A fracture (A-C); 2) to plan in detail the positioning of the rings of the hybrid CEF and the length of the connection struts (D). To facilitate connection of the devices, it is necessary to measure the distance between the second ring and the knee flexion-extension axis on which the body of the HEF is centered: this space must be approximately 150 mm (E). The patient was positioned on the fracture table to use ligamentotaxis for reduction (F). Before starting, under fluoroscopic control, reference points are marked on the skin (G).

later confirmed on total body CT which excluded other injuries to internal organs. In emergency, after placement of a chest drain, damage control orthopedics was performed with temporary knee bridging EF; subsequently, a CT scan of the leg was performed (Fig. 1) following the flow chart "spam, scan, plan". The choice of the next therapeutic step was born from her general conditions and that of tissues: these suggested a surgical strategy that allowed early stabilization, to quickly recover sitting and standing, without the ORIF related risk of soft tissue dissection, which already appeared dystrophic and significantly swollen. Therefore, we chose to perform synthesis of the joint fracture using PRIF with cannulated screws. To avoid secondary collapse of the articular surface, the "raft" support is given by k-wires crossed on the first of the three rings of the CEF, which are also responsible for controlling the axis, length and rotation at the metaphyseal level, according to the Catagni assembly models [2] and the CEF principles well described by Salomone [9]. To allow safe weightbearing (already sarcopenic before the trauma), we decided to use Marcacci's HEF characterized by an axial load tolerance suitable for our purpose.

CT study was fundamental to:

- plan the synthesis with cannulated screws in compression the articular fracture that would allow the transformation of the type C into type A fracture (Fig. 2);
- plan in detail the positioning of the rings of the hybrid CEF and the length of the connection struts; the first ring (proximal) is positioned starting from the proximal k-wire which will be just distal to the cannulated screws. Then we place the k-wires in a crossing figure to create the raft system and to support the articular surface. On the second ring an olive K-wire aiming is mounted to correct the valgus deformity (metaphyseal region distal to the fracture). To facilitate the connection of the devices, it is necessary to provide the distance between the second ring and the knee flexion-extension axis on which the body of the HEF is centered: this space must be approximately 150 mm, i.e. the distance between the center of rotation of the HEF and the most distal

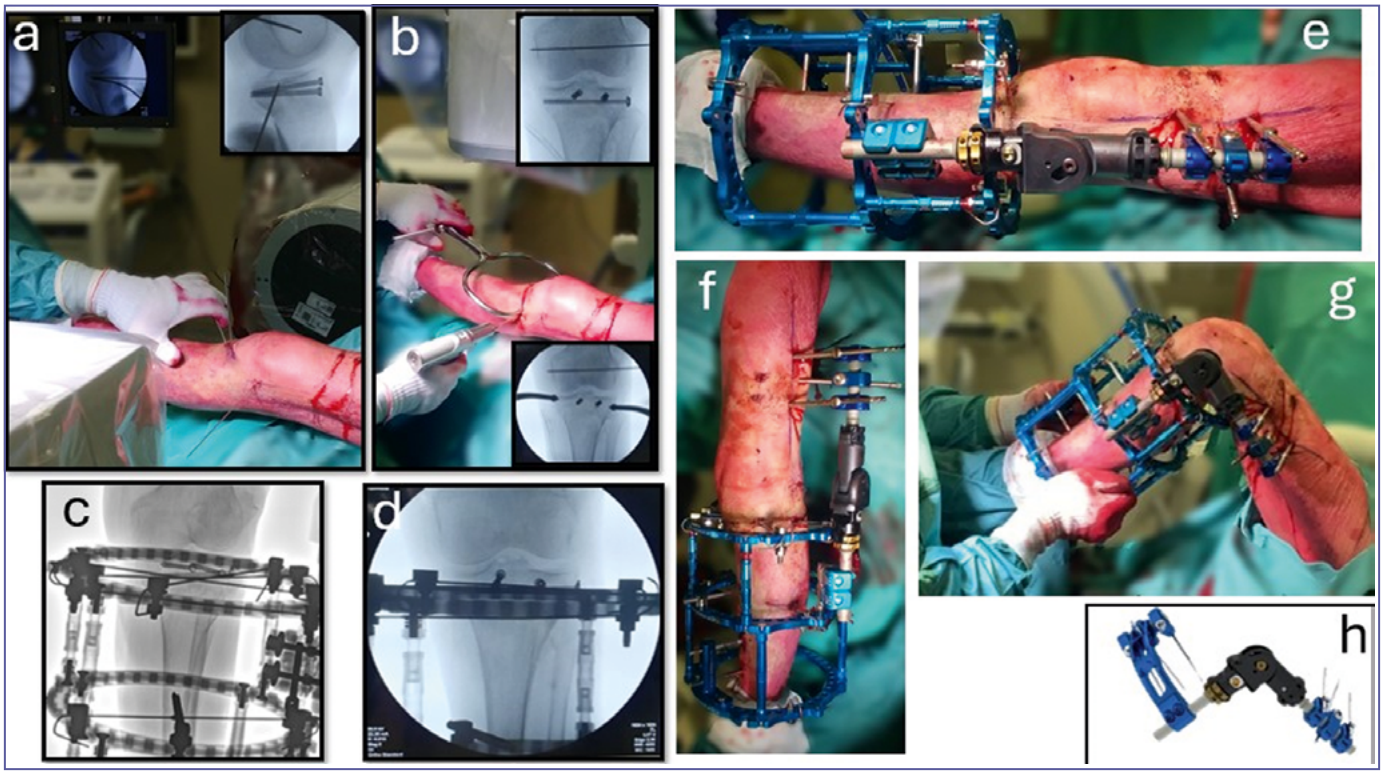

Figure 3. Under fluoroscopic control, reduction of the joint fragments is first carried out using a percutaneous technique, followed by osteosynthesis with three 4 mm cannulated screws (A,B). To avoid secondary collapse of the articular surface, the "raft" support is given by the k-wires crossed on the first of the three rings of the CEF (C,D). The knee HEF is positioned by sliding it over the K-wire positioned previously on the center of rotation of the knee, fixed to the femur with 3 pins and connected to the second ring of the circular EF with special clamps, reconstituting the mechanics of the original HEF (E-H).

point of its tibial arm; on this arm the connection will take place with the second ring with special clamps, reconstituting the mechanics of the original HEF without modifying that of the CEF. The distal ring, placed parallel to the articular rim of the tibia (due to distal k-wire), will be fixed to the bone with hydroxyapatite (HA) coated pins. Measurement of the distance of the rings is crucial to plan the length of telescopic connection struts and allow to correctly perform the procedure and to shorten surgery times.

The patient was positioned on the fracture table to use ligamentotaxis for reduction and easy use of the C-arm to take image intensifier views. Before starting, under fluoroscopic control, the following reference points are marked on the skin (Fig. 3):

- knee center of rotation on the femoral condyles (for positioning the K wire) according to Marcacci's technique [7];
- knee and ankle joint rim;
- fracture level;
- level of the proximal and distal k wires, the position of the rings and the distances between them which are used to pre-assemble the CEF body.

Under fluoroscopic control, reduction of the joint fragments was first carried out using a percutaneous technique, followed by osteosynthesis with three 4 mm cannulated screws: two in the antero-posterior direction and one in the lateral-medial direction with washer. Next, the three-ring CEF was applied, placing two k-wires parallel to the joint line of knee and ankle joint (on the proximal and distal ring). At the proximal ring, 4 crossed k-wires were positioned; an olive K-wire was positioned on the intermediate ring for the correct varus-valgus reduction, and then fixed by a 6 mm (HA) coated pin; the third distal ring was stabilized with two 6 mm pins. The knee HEF was positioned by sliding it over the K-wire positioned previously on the center of rotation of the knee, fixed to the femur with 3 pins, and connected to the body of the circular EF with special clamps (Fig. 3). During the operation by image intensifier, the reduction in multiple planes, the tibial axis and finally the range of motion were evaluated. Active and passive knee mobilization and weightbearing "as tolerated" protected by a walker were allowed immediately. The patient was discharged home after 5 days. At the 30-day clinical and

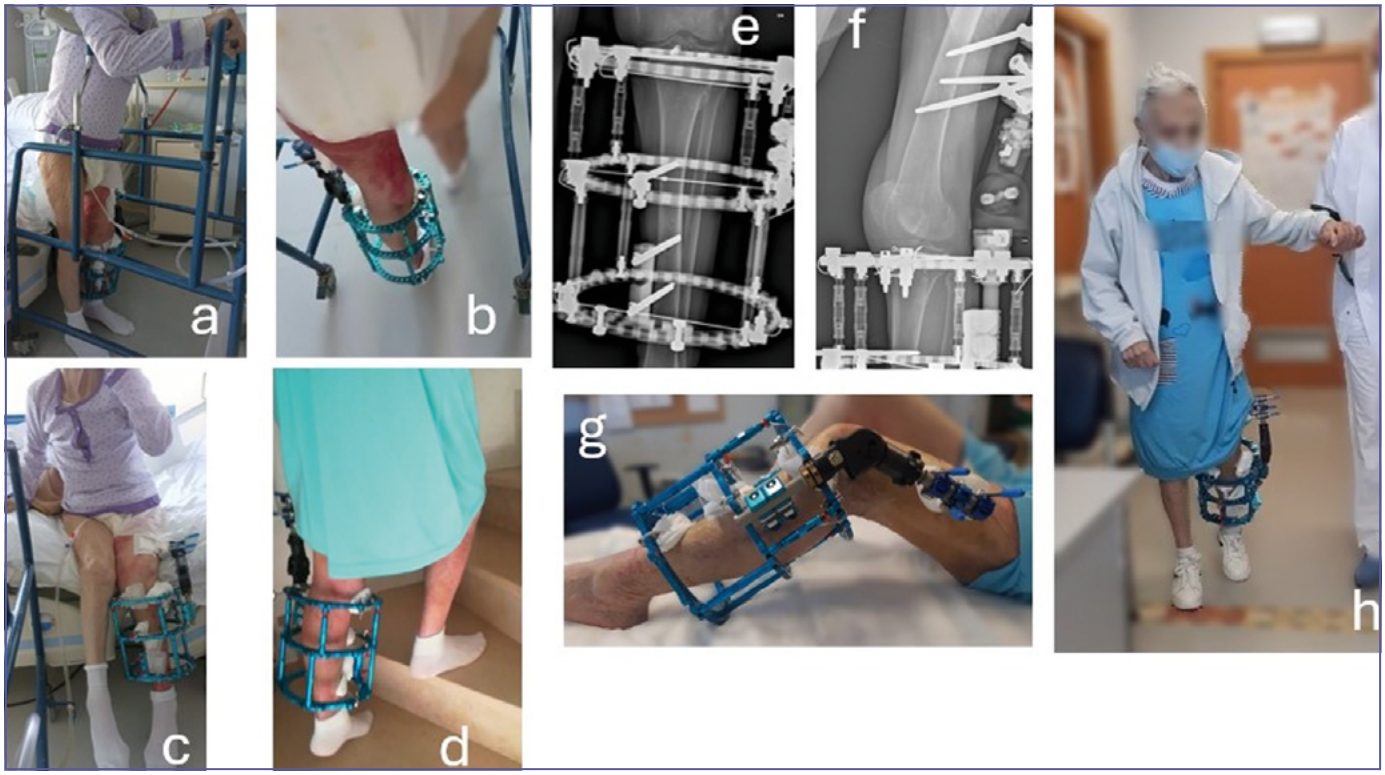

Figure 4. Active and passive knee mobilization and weightbearing "as tolerated" protected by a walker were allowed immediately (A-C). After 20 days, the patient was able to go up and down the stairs of her house (D). At the 30-day follow-up she was able to walk with essentially full weight bearing without crutches with limited flexion due to the proximal ring of the EF (G,H). X-rays showed no loss of reduction (E,F).

radiographic follow-up, the patient was walking with a substantially complete load without crutches, and she was able to go up and down the stairs of her house after 20 days. X-rays showed no loss of reduction (Fig. 4). After 50 days, the HEF and its femoral screws were removed during clinical and radiographic follow-up. At 3 months the patient was walking without support and the radiographic check showed metaphyseal healing. After 100 days the CEF was removed. Clinical follow-up at 6, 12 and 24 months showed joint recovery of ROM (0-110°) without pain on loading, and X-rays showed no subsidence of the joint plane or signs of post-traumatic arthritic degeneration (Fig. 5).

Discussion

The benefits of early surgical treatment of femoral neck fractures in the elderly in terms of lower mortality are known; there are no studies that highlight the same benefits in case of early loading in lower limb fractures [10]. However, the negative effects of being bedridden and prolonged hospitalization on frail patients and the resulting social care costs are known. While ORIF is the gold standard treatment even in elderly patients, it is always conditioned by the state of soft tissues; in these people, the skin and subcutaneous tissue undergo involutional phenomena linked to aging and concomitant pathologies. In case of soft tissue damage with uncertain evolution, the definitive treatment is postponed for days or weeks opting for two-stage treatment. Looking for early fracture stabilization that would allow immediate weightbearing, we exploited well-known concepts of external fixation that were reinterpreted in a modern light thanks to the evolution of biomedical engineering, inspired by Appley's words: "Very few ideas are truly "new" in surgery… most new ideas are simply revivals of old ones, long buried in the mists of time, lost to the vagaries of fashion and passing fads, or abandoned because the technique lags behind the imagination. These ideas may reawaken when the time is ripe. External fixation is a typical example" [11]. The treatment of complex fractures of the proximal tibia using PRIF with cannulated screws combined with external fixation has long been known [1,2]. The combination of compression screws and k wires crossed just distal to these to support the joint plane recalls concepts of construction engineering, and conceptually reproduces the "rafting technique" described in the synthesis with angular

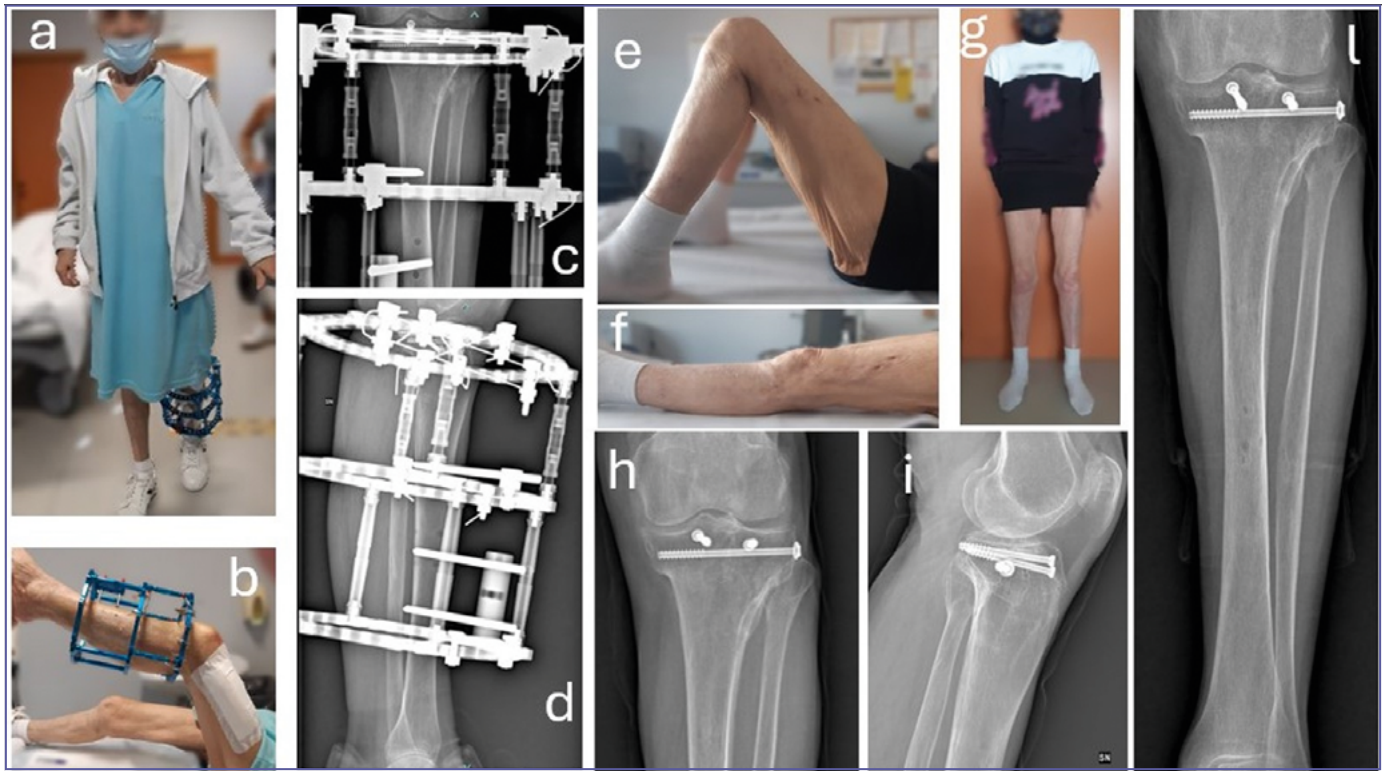

Figure 5. After 50 days, the articulated fixator and its femoral screws were removed during clinical (A,B) and radiographic follow-up (C,D). At 24 months, clinical follow-up (E-G) showed joint recovery of ROM (0-110°) without pain on loading, and X-rays showed no subsidence of the joint plane or signs of post-traumatic arthritic degeneration (H-L).

stability plates. In selected cases, where joint fixation appears possible on CT study, this technique allows for early fracture treatment without risks to soft tissue associated with ORIF. In this case, the CEF used (CLICKIT CF, MIKAI SpA) has advantageous structural characteristics: low weight, due to the aluminum composition of the rings. The total weight of the entire system, excluding screws and wires, is approximately 1.1 kg, resulting in minimal impact to patients. The presence of quick-attach telescopic struts with specific spaces on the ring leaves the other holes free for k-wires and screws: this makes assembly easier during the intervention.

Hinges have been used for some time in the treatment of knee joint fractures with Ilizarov systems [4,5]. In this case, the hinge is not a simple accessory of the circular system, but a unilateral articulated fixator with its own mechanical characteristics. The system we used (ST.A.R 90 F4 knee, Citieffe srl) has three features that guided our choice:

- allows a greater degree of flexion than standard hinges (90° *vs* 40°) due to a system based on the knee four-bar model that replicates the posterior rollback of the femoral condyle on the tibia during flexion, with less tension on the capsular and ligament structures;
- withstands an axial load of 0.77 kN (equal to 78.52 kg) verified in mechanical tests carried out in the worst configuration for the certification of the system;
- can carry out a micrometric distraction of the joint due to a special bezel (metal ring) in the tibial arm of the device;
- the combination of these techniques made it possible to treat the fracture and mobilize the knee early, but foremost to provide increasing weight-bearing based on the pain with great advantages of the patient's recovery of autonomy and management of care.

As always, alongside the advantages there are disadvantages. In external fixation the most frequent complication is linked to recurrent episodes of pin site infection. However, an accurate operating technique, the use of some measures such as HA coated pins, and careful follow-up may reduce the complication rate. In this case, the presence of two or three femoral pins and the steric encumbrance can reduce the tolerance of the implant compared to a classic CEF. However, we believe that this system can be used in selected cases, both because the treatment with the HEF keeps approximately two months, and because of the advantages that can be obtained.

Conclusions

While we are aware of the lack of significant data, the small number of cases and the technical limits of a hybrid construct created from two independent systems, we are convinced of the validity and the rationale of this procedure. The possibility of treating even the most complex fractures combining percutaneous screw fixation and CEF can be considered a good option in selected cases to prevent excessive insult to soft tissues. The HEF and early weight bearing can improve the patient's autonomy and in some cases avoids being bedridden. For this reason, this idea could be the basis for future studies to evaluate its real benefits and to improve the biomechanics of the system.

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Conflict of interest statement
The Authors declare no conflict of interest.

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Author contributions
AI: conceptualisation, ideation, planning and surgery performing, patient follow-up, writing, review and editing original draft Rossella Sirianni: review and editing of the original draft; MD'A: conceptualisation, patient follow-up; MA: surgery performing; LB: literature review; GN: image case report review; MP: supervision; MM: conceptualisation, supervision.

Ethical consideration
Not applicable.

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