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Rational solutions for the treatment of frail patients: joint arthrodesis

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Summary

Limb deformity correction in scheduled patients allows the surgeon to perform the surgical procedure in the best condition considering both timing and surgical indication for the procedure. Such principles cannot be observed in two clinical scenarios: demanding surgical procedures in patients with poor local and general clinical conditions, and need for reintervention in critical patients who previously underwent surgical procedures in ideal conditions. The combination of such aspects defines the clinical scenario of the frail patient who is not amenable to invasive surgical procedures that are otherwise routinely performed in good clinical conditions. However, in such patients it is of paramount importance to identify a surgical procedure that, although minimally invasive, is able to restore limb function and improve patient's quality of life. Joint arthrodesis, thanks to renewed surgical techniques and modern devices, has regained a primary indication in patients with frailty.

Key words: frail patient, joint arthrodesis, limb deformity, joint infection, salvage limb procedures

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Frailty is defined as a clinically recognizable state of increased vulnerability involving the patient as a whole or a distinct body district and can be associated with pathological conditions requiring specific and urgent medical or surgical treatment. Fried et al. [1] defined frailty as a physiological syndrome consisting of reduced functional reserve of the patient with a limited tolerance to external stressors and caused by a cumulative decline in multiple physiological systems causing the patient's vulnerability to adverse conditions. Such a definition was primarily meant to delineate the frail elderly, but has been later used to generally identify patients who, irrespective of their age, are more prone to medical and surgical pathological conditions because of their clinical status. Gobbens et al. [2] defined frailty as a dynamic status involving individuals with loss of one or more functional domains (physical, psychological, and social), caused by the influence of several variables that increase the risk for adverse health outcomes. Actually, frailty is considered as a multidimensional condition, involving not only the mere biological aspects, but also the social and psychological ones and it can affect in several ways many surgical treatments, influencing clinical conduct and surgical treatment. In 1892, William Osler stated that "It is more important to know what sort of patient has a disease than to know what sort of disease a patient has" (Remark on specialism).
Joint arthrodesis, that is the fusion of a joint with degenerated articular surfaces, has been in the last century the golden standard procedure for the treatment of limb deformities, post-traumatic arthritis, and bone infections; the treatment goal was to restore the weight bearing capability of the affected limb despite the loss of motion in a degenerated joint. Such a surgical procedure was later clouded by the superior results of prosthetic replacement, bone reconstruction, and fixation techniques. However, the great

success in orthopaedic surgical procedures obtained in recent decades and the increase in the request for surgical procedures have caused a higher incidence of failures and complications than in the past. The impossibility to perform highly invasive revision procedures for failed bone fixation or joint replacements due to non suitable patient's medical status has renewed the interest for joint arthrodesis as a primary indication for such patients in order to gain functional recovery of the limb. The improvement in the technical characteristics of modern fixation devices has made joint arthrodesis a more tolerable treatment for the patient with better functional results and a broader spectrum of indications.

Indications and treatment modalities

The main goal of joint arthrodesis is to abolish joint motion and pain caused by it in a degenerated joint and to restore the limb function such as, for example, weight bearing ability in the lower limb and hand prehensile function in the upper limb. Joint arthrodesis in the frail patient as a salvage procedure following severe limb trauma or prosthetic replacement failure or in metabolic, haematological and neuromuscular diseases, represents a concrete possibility for limb salvage and limb function preservation, although limited.

Such therapeutic choice requires thorough patient assessment and accurate evaluation of the correct arthrodesis method and, as much as possible, of the limits, technical modalities and possible complications of the surgical procedure. Patient assessment should also involve social aspects defined as economical, familial and psychological characteristics of the patient. It is of paramount importance that before starting the therapeutic process, adequate explanation of the aims of the surgical procedure and its concrete benefits is offered to the patient, highlighting that joint arthrodesis is meant to improve the quality of life and to obtain functional recovery of the limb, but that a complete "resititutio ad integrum" of the patient is not possible. In order to assess the functional autonomy of the patient, the "Clinical Frailty Scale" proposed by Rockwood et al. [3] is an evaluable assessment device. The ability and willingness of the patient to join the new offered therapeutic possibility has to be supported by both a social and familial net. Moreover, the patient has often to accept surgical treatments involving the use of external fixation devices, which although represent the only possible solution in many cases, may be the cause of physical and psychological discomfort. Thorough assessment of the limb through accurate analysis of all the steps of the surgical procedure to be performed should always take into account the possible complications related to surgical planning and clearly state the therapeutic goals. A weight-bearing x-ray examination of the lower limbs associated with computed tomography (CT) study with 3D reconstruction of the joint is mandatory. We can distinguish between a functional arthrodesis (also known as *in situ* arthrodesis) whose aim is to fuse the joint by maintaining alignment of the bone segments without any form of correction of their axes and a "corrective" joint arthrodesis where joint fusion has to be associated with axial deformity correction obtained by articular or periarticular joint osteotomy (Fig. 1). A corrective osteotomy is always recommended in cases of joint degeneration associated with axial deformity in order to restore the limb axis and obtain a proper working joint arthrodesis. Although a renewed interest has been observed for knee and ankle joint arthrodesis, hip joint fusion as a salvage procedure is no longer performed due to the inherent technical difficulties to obtain a stable fusion and mainly because of the high functional limitations of the entire lower limb.

In the present paper, we describe the methodology that we developed in both deformity analysis and surgical planning during our surgical practice between 2008 and 2019 at the Department of Orthopaedics and Traumatology of "Sapienza" University in Rome in the complex limb reconstruction unit dedicated to the treatment of the sequelae of prosthetic revision procedures failures and of post-traumatic, infectious, metabolic and heamatological diseases in the knee and ankle joint.

Skin

Skin examination is an indirect index of the soft tissue trophism and quality of the affected segment to be treated with arthrodesis. The presence of skin lesions or ulcer influences the choice for an internal or external fixation device. It is important to assess wheth-

Figure 1. Simultaneous correction of knee and ankle deformities; pre-operative: outcomes of poliomyelitis of the left lower limb. (A) post-operative; (B) post-operative x-ray; (C,D,E) knee arthrodesis with carbon frame according to Charnley, ankle arthrodesis with retrograde nail.

er skin ulcers are caused by mechanical causes such as compressive forces exerted by bone prominences such as in Charcot's foot disease, by metabolic causes such as in diabetes, or by different conditions such as infections or tumour. Although the indication to perform a joint arthrodesis is self-evident, the causes of a skin lesion should always be identified because of their importance on the choice of the surgical conduct and type of arthrodesis. Mechanical compressive ulcers are caused by a progressive bone degeneration that puts tension on the subcutaneous tissue; the ulcer does not heal without bone resection or restoration of the articular shape. It is frequently observed in ankle and foot districts. Skin ulcer secondary to bone infection is the consequence of a fistula causing purulent drainage in a periarticular site. It is frequently observed in the knee joint after prosthetic replacement; knee prosthesis removal and bone debridement are the mainstay for ulcer healing and successive joint arthrodesis. Chronic skin ulcers dating back years and with no tendency to healing, may be the site for skin tumour development. Such lesions, require a bone morphology study, microbiological study and histological examination of the surrounding soft tissues. It is important to understand that ignoring the cause of the skin lesions seriously compromises the chances to obtain functional recovery of the limb and proper joint fusion.

Soft tissues

Many joint deformities following peripheral or central nervous system lesions are caused by the lack of use of appropriate splints or prolonged bed rest. Joint stiffness and ankylosis may occur without bone lesions. Joint arthrodesis represents, in most of these cases, the only possibility to obtain a foot plantar based or a knee extended deambulation. Tibio-tarsal arthrodesis, in such patients, and less frequently knee arthrodesis, requires ancillary procedures such as tendon lengthening or tenotomy due to foot fixed plantar flexion and knee flexion; by performing it, it is possible to restore correct limb weight bearing function without performing periarticular bone osteotomies. Joint fusion is obtained putting the limb in a functional position for several months by the use of splints or external fixation systems, until ankylosis occurs, with no need for further surgical procedures [4].

Bone stock

The patient's bone stock can be impaired or reduced not only because of senile and post-menopausal osteoporosis, but also because of metabolic disease, tumours, medications, previous trauma, bone infection, or joint prosthesis revision procedures (Fig. 2). Although joint arthrodesis is a logical solution for treatment of several disabling conditions of the musculoskeletal system, it is the local condition of the bone that makes it possible to perform the surgical procedure and make it an effective treatment. The lack of axial deviations and the presence of an isolated articular surface degeneration allows performing in situ arthrodesis. This is the easiest technical solution and requires a good bone quality of the entire segment in order to allow the placement of an internal fixation device or an external fixation frame; a periarticular soft tissue with good vascular support is mandatory to obtain a bone fusion.
An x-ray examination of the involved segment reveals the bone quality according to endosteal morphology, cortical bone thickness, epiphyseal cancellous bone uniformity or mass reduction, and the presence of osteolysis or calcifications with irregular margins. If there is doubt on the scarcity of available bone in the affected segment potentially compromising bony fusion, it is wise to perform a bone biopsy to evaluate the quality of bone tissue before the definitive procedure is performed. A CT examination with 3D reconstructions is highly reliable for the study of the fusion area and gives data on cortical bone stock (regular cortical bone stock) and cancellous bone stock. In case of reduced bone stock, it is often sufficient to use a bone graft harvested from the iliac crest to perform a joint arthrodesis [5]. The use of synthetic bone substitutes is not recommended because of the longer integration time and the need for a normal vascular and tissue support.

Articular surface preparation

Joint arthrodesis requires the presence of adequately prepared articular surfaces on both the sides of the joint. This is performed, when no bone deformities are present, by resecting the subchondral bone with respect to the longitudinal axes of the bone segments.
The surgical approach to the knee joint is always performed through a median anterior incision and a standard medial parapatellar approach if no contraindications are present. Femoral and tibial bone cuts should be parallel to each other and perpendicular to the femoro-tibial axis. The cutting line can be identified with the use of Kirschner wires guiding the resection (Figs. 3-4). The patella can be removed and the quadriceps tendon be sutured to the surrounding tissues; sometimes, the patella can be used to fill bone defects. The surgical approach to the ankle joint for arthrodesis is mainly anterior unless axial deformities correction is required; if it is the case, a transfibular or pure medial approach can be used for deformity correction and joint corrective arthrodesis. In the presence of severe joint degeneration or deformity of the knee and ankle, it is necessary to perform wide resections to obtain regularly shaped and stable congruent bone arthrodesis surfaces. In such cases, some issues may be present: excessive limb shortening, bony fusion of two bone segments with different diameter, lack of fusion, or non-union of the arthrodesis site.

Fixation

Appropriate osteosynthesis after bony surface preparation at the fusion site is extremely important to obtain fusion in both the knee and ankle joints, with the correct timing (in general, 4 or 6 months). Intramedullary fixation is contraindicated in case of previous bone infection. The retrograde intramedullary nail for ankle arthrodesis has several technical and psychological advantages because it allows for faster recovery.

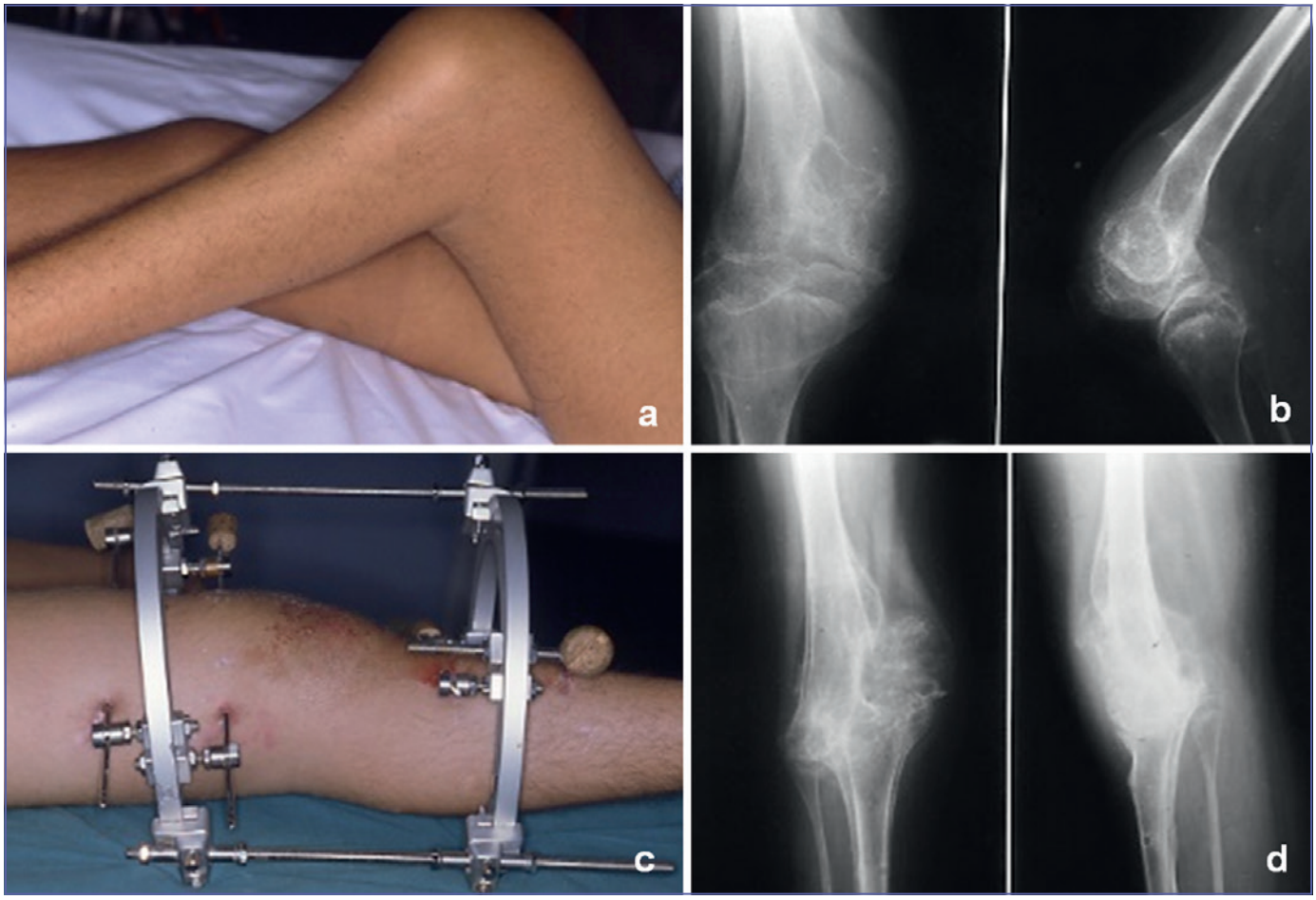

Figure 2. Arthrodesis with external fixation in patient with haemophilic arthropathy; clinical deformity in flexion of the left knee (A) femoral cyst reabsorption, posterior tibial dislocation x-ray; (B) correction of deformity and arthrodesis with EF; (C) post-operative x-ray; (D) knee extended, complete joint fusion.

Intramedullary fixation has a more limited indication in knee arthrodesis, and is performed more frequently in patients with previous infectious processes that required knee prosthetic removal. When treating patients with history of previous joint infection disease and with bone defects caused by joint prosthetic removal, combined techniques of bone reconstruction and bone loss treatment are required, and intramedullary devices for knee fixation are contraindicated, also considering the required length of the device itself to stabilise both the tibia and femur.

External fixation is the most suitable technique to perform functional and corrective arthrodesis: the external fixator device exerts a uniform compression, allows for alignment correction and patient weight-bearing according to the frame characteristics and does not interfere with the amount of bone graft required. However, the patient's intolerance to external frames is the main drawback with its use, although less cumbersome devices are now available. Frame stability is the most important aspect for patient mobilization and a rapid healing. The most stable devices are circular frames or monoaxial frames with a four-sided frame configuration (Charnley's quadrilateral frame). In case of more than one joint per time requiring arthrodesis, different surgical techniques involving internal and external fixation devices can be used in combination to reduce the impact of multiple external frames on the same limb. Otherwise, it is possible to perform the deformity correction by initially applying an external fixator and then proceed to the conversion with an internal fixation device [6].

Complications

Minor complications, which we do not report on in this section, are the same as other bone fixation procedures and do not generally jeopardise the final result of the surgical procedure. Major complications potentially influencing the results of the surgical procedure are the absence of bone healing at the arthrodesis site and secondary deformities that reduce or erase the functional value of the arthrodesis itself.

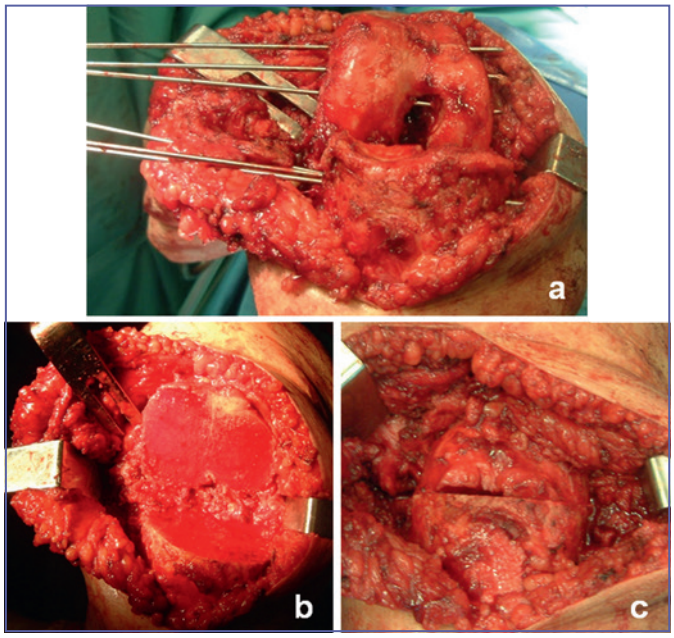

Figura 3. Preparation of the knee joint surfaces; K-wires used as a cutting guide (A) resection of the joint extremities; (B) juxtaposition of bone.

Non-union of the arthrodesis

The lack of bone fusion at the arthrodesis site should not be ascribed to patient's general conditions or behaviour, because clinical conditions, metabolic and psychological status and the risks correlated with the surgical procedure should be evaluated before the surgical procedure is started. Surgical planning is not the strict repetition of what is routinely performed, but requires an adjustment according to the patient's characteristics and type of intervention. Although the arthrodesis procedure is a salvage procedure for failed joint replacement or post-traumatic sequelae, more often associated with several pathological conditions, it is not an easier or faster procedure than others. It is not a replacement nor a primary fixation procedure, but has a merely biological nature where bone stability, vascular pattern, bone surface congruence and bone stock are fundamental. The lack of these prerequisites causes the failure of bone fusion that manifests in different patterns: pure non-union or incomplete or circumferential fusion. Non-union refers to the lack of bone healing at the arthrodesis site and is associated with severe deformity of the limb, swelling due to vascular flow obstruction and intolerance to weight bearing. In such cases, a critical analysis of the previous procedure and CT examination with attention to the vascular axis is mandatory before performing a revision procedure. A partial fusion is the consequence of an insufficient contact between the arthrodesis surfaces. If less than 50% of the bone fusion site has healed, the patient complains of persistent pain. When a sufficient waiting period has elapsed, it is indicated to proceed with a bone grafting procedure consisting of a corticocancellous bone graft application in the non-union site or a complete revision procedure of the bone surfaces. The circumferential fusion of only the cortex is typical of arthrodesis following knee replacement failure: the removal of prosthesis components form the infection site, especially when a revision prosthesis has been implanted, and creates a cavity with loss of cancellous bone. The removal of cortical bone in these cases should be avoided due to the excessive shortening of tibia or femur and bone filling with cancellous bone or cement and external fixation is recommended. In cases of non-integration of the graft and failure of the debridement procedure, a cavitary arthrodesis is created: although functional, the underlying infectious process and fistula still remain.

Shortening

Lower limb shortening because of arthrodesis is the consequence of subchondral bone cuts aimed to obtain flat and congruent surfaces. Limb length discrepancy causes deambulation with plantar flexed ankle and extended knee, according to the arthrodesis site. If a major length discrepancy exists because of the need

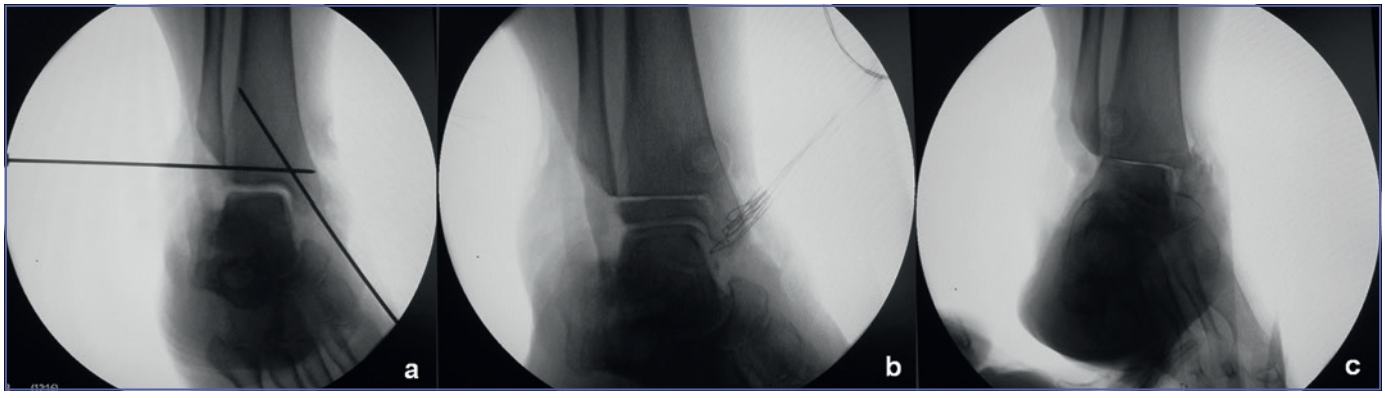

Figure 4. X-ray: preparation of the ankle joint surfaces; K-wires used as a cutting guide (A) resection of the joint extremities; (B) juxtaposition of bone surfaces (C).

for more invasive debridement and bone resection, an associated procedure is required to make the limb functional. Bone lengthening techniques using internal or external devices allows good recovery of the length discrepancy, but can be contraindicated in a frail patient due to age, non-compliance, or general medical conditions. Bone transport allows to perform the arthrodesis at the docking site and to regain correct limb length through bone regenerate in distraction. It does not need an autologous bone graft, but a longer period of time on fixator (several months). Limb length restoration with autologous or mixed bone graft can also be realised with the induced membrane technique and an internal device despite major surgical invasiveness [7]. When an arthrodesis has to be performed in a hypometric limb, the choice is between fast recovery of the limb function but with use of orthotics or bone lengthening through a longer procedure.

Axial deviations

Limb alignment defect following arthrodesis may sometimes occur in children when treated before skeletal maturity, as a consequence of severe trauma or infection. In both the knee and ankle, deformities are mainly located in the coronal plane with valgus or varus deviation. In the adult patient, such deformities after joint arthrodesis are less frequent because of the absence of residual statural growth. The revision procedure requires assessment of the angular deformity, length discrepancy secondary to axial deviation and the fixed lumbar spine compensatory curves that can contraindicate limb length discrepancy correction. Revision osteotomy of an arthrodesis site is a complex surgical procedure due to the need for new bone resection in the site of the previous arthrodesis, the need for bone corrective osteotomies and the need for a new bone fixation with a longer healing time. This is why it is not indicated in frail patients unless a compelling clinical need is present.

Limb rotatory malalignment

Limb rotatory malalignment following knee or ankle arthrodesis causes a secondary deformity of the foot that can be externally or internally rotated, independently of the surgical site. Limb rotatory alignment is more difficult to assess and check intra-operatively than the limb length discrepancy. The external rotation of the foot affects the plantar support and has an aesthetical impact. The internal rotation of the foot hinders deambulation because of the forefoot colliding with the foot of the opposite side. The prevention of this complication during an arthrodesis procedure mainly consists in the clinical and radiological comparative evaluation of the limbs and in the use of a computer assisted system of hexapod external fixation that allows symmetric limb alignment even in the post-operative period.

Conclusions

Joint arthrodesis is a salvage surgical technique used in cases of therapeutic failures or in cases where it is necessary to restore weight bearing function of the ankle or knee. In frail patients, it is a preferable technique because of the need for a fast and efficient surgical procedure. However, this does not imply that it is an easier procedure, not only because of the clinical conditions of the frail patients, but also because of the unique challenge to recreate the anatomical and biological conditions for appropriate healing. A procedure that is too invasive or a prolonged hospital stay may turn a rationale solution for the frail patient into a worsening of their condition.

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

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Authors' contributions
MM designed and wrote the manuscript; PM realized graphical art; PS wrote and revised the manuscript and figures.

Ethical consideration
According to the current law of our country and due to the restrospective nature of the present study, no ethical committee approval was required for the present study.

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