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Original article

The *"Ball in Basket"* Technique for Tibiotalocalcaneal Fusion

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Summary. Tibiotalocalcaneal arthrodesis (TTCA) in severe bone deficit represents a complex challenge for expert orthopedic surgeons also. This study aims to illustrate a surgical technique, defined as "ball in basket", that facilitates the fitting of the structural bone graft (femoral head from bone bank) and its placement, in order to fill the bone gap during instrumented arthrodesis. The proposed technique includes the preparation of the recipient bone surfaces with acetabular convex reamers and of concave reamers to shape the bone graft from bone bank. This preparation guarantees a maximum congruence of the bone surfaces and a greater stability of the bone graft during the placement of the fixation devices to optimize the bone fusion and to provide a good patient clinical outcome. The preliminary results obtained for two patients, initially presenting with severe anatomical deformity associated with severe bone gap, are described. Patients underwent clinical and radiographic follow-up evaluations (respectively at 4 and 30 months of follow-up) showing radiographic healing and good functional recovery. The results are encouraging, although long-term studies and a wider cohort of patients are necessary to consider this technique a reliable aid in case of severe bone deficit. (www.actabiomedica.it)

Key words: Tibiotalocalcaneal, TTCA

Introduction

The arthrodesis procedure is recommended in case of severe joint disease or severe deformities. The indications for arthrodesis include severe instability of bone and ligaments, surgical revision of ankle prostheses or previous arthrodesis, bone defects secondary to neoplasm or traumatic injuries. Other additional indications consist of post-traumatic arthritis, avascular necrosis of the talus, degenerative rheumatic diseases, Charcot neuroarthropathy, deformities secondary to neuromuscular diseases (1,2, 3).

In particular, the most frequent indications in relation to the tibiotalocalcaneal arthrodesis (TTCA), that includes the subtalar joint in the fusion, are the failure of ankle implant (70%), the failure of a previous arthrodesis (20%) and the traumatic injury (10%) (4).

In literature, more than 30 techniques of tibiotalocalcaneal arthrodesis with different surgical approaches and fixation devices are described. The elevated number of different alternative methods derives from the fact that the complication rate can reach, based on the clinical records, the 50% as well (1).

Therefore, the variability of the results dictates the research of an appropriate solution aimed to guarantee the best possible stability of the bone graft and the stabilization of the arthrodesis with an adequate fixation device.

Numerous fixation devices are available for the joint fusion surgery, although the intramedullary nailing provides a few advantages as compared to other fixation systems including the preservation of the alignment, of the length and of the stability of the anatomical segment and an increased rigidity of the construct (5).

The TTCA performed with intramedullary nailing was described for the first time by Adams in 1948, whereas in 1994 Kile et al. published the retrograde intramedullary nailing technique, supported by a variety of studies (6-8).

The entity of the contact area represents a fundamental factor in the process of the fusion of two bone segments (9-11), for this reason a severe loss of bone stock represents a condition that can compromise the result, as well as increasing the difficulty of the surgical procedure.

The most frequently used bone graft techniques to fill the segment deficit are the iliac crest tricortical bone grafts and the allografts (12-14).

In literature, the reported success rate regarding the different bone graft techniques of structural *autograft* or *allograft* vary from 48% to 93%, based on the analyzed case studies and on the proposed technique (4, 9, 11, 15, 16).

The allografts, with no living cells, provide the structure and the matrix of the bone tissue for in situ colonization (11). These grafts are absorbed by the host more slowly than an autograft since they can generate an immune response that can potentially delay the osteoinduction phase.

For this reason, it is significantly important to generate a construct that provides the maximum possible stability.

Hence, finding an appropriate solution to guarantee the maximum possible stability of the graft and the stabilization of the arthrodesis with an efficient fixation device becomes fundamental.

Nonunion of the bone segments, infections, delayed healing of the surgical wound, neurovascular lesions, arthritis or rearfoot joint laxity, misalignment, chronic swelling, stress fractures, often due to a change in the weight-bearing distribution, and painful scar tissue (2) represent a few of the possible complications.

The most frequent complication is the nonunion of the anatomical segments, reported in literature with values between the 11% and 40%, related to the avascular necrosis of the talus (1) in most cases.

The reported failure percentage results even higher if a revision surgery of a previous arthrodesis is required. This highlights the importance of an accurate patient selection, a precise surgical technique, and a monitoring of the outcomes over the time (17).

This study analyzes two cases treated with TTCA with retrograde nailing and structural *allograft* prepared following the *"ball in basket"* technique, for two different diseases: a traumatic injury and a severe rearfoot deformity secondary to subtalar arthrodesis and placement of screws.

Materials and Methods

The used technique consists of preparing the site of the graft and the graft itself following the *"ball in basket"* technique once the joint is reached with the most adequate surgical approach.

The expression *"ball in basket"* for this type of technique is due to the high congruence between the receiving site and the bone graft. The preparation of the new cavity between the talar articular surface and the distal tibial articular surface was performed with EP-Fit™ Smith & Nephew (Smith&Nephew AG Aarau - CH) (Figure 1) convex acetabular reamers with increased diameter, whereas the preparation of the femoral head was performed with (Wright Medical Group N.V. Memphis Tennessee - USA) convex humeral head reamers with decreased size holding the graft still with Codivilla type reduction forceps. (Figure 2, 3)

Thus, the contact surfaces result more uniform, granting a higher congruence and stability (Figure 4).

A Valor™ (Wright Medical Group N.V. Memphis Tennessee - USA) retrograde intramedullary nail was carefully chosen as fixation device in both cases to stabilize the construct.

Clinical and radiographic follow-up evaluations showed radiographic healing.

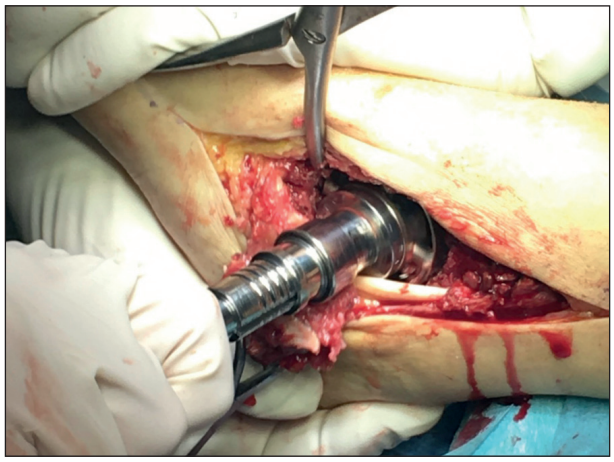

Figure 1. preparation of the new cavity

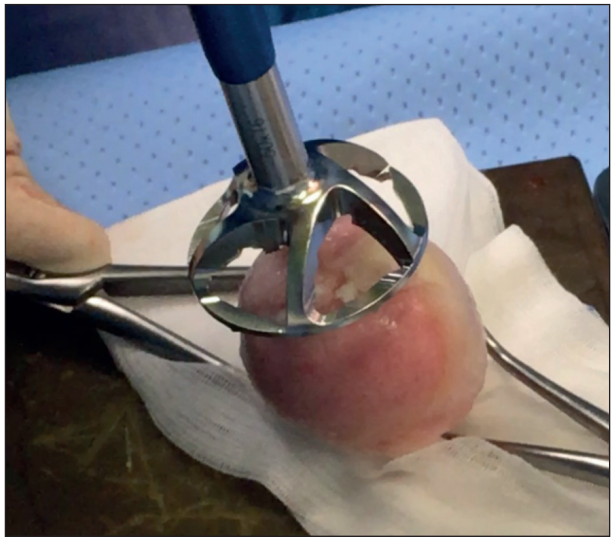

Figure 2. Femoral Head Preparation

Case 1

Female patient of 15 y/o arrived at the Emergency Room of San Bortolo Hospital of Vicenza following to a severe fall-related traumatic injury with evidence of multiple abdominal contusions (pulmonary, hepatic, and renal injuries), multiple vertebral fractures and upper and lower extremities fractures respectively burst fracture of the talus and calcaneus and fracture of lateral aspect of the calcaneus, bimalleolar fracture, 4th metatarsal fracture and cuboid fracture on the right side and calcaneal fracture-dislocation, talar body fracture, lateral malleolus fracture and cuboid fracture on the left side (Figure 5 a/b/c). Hemodynamic stabilization and neurosurgical procedure of vertebral stabilization of patient were performed urgently.

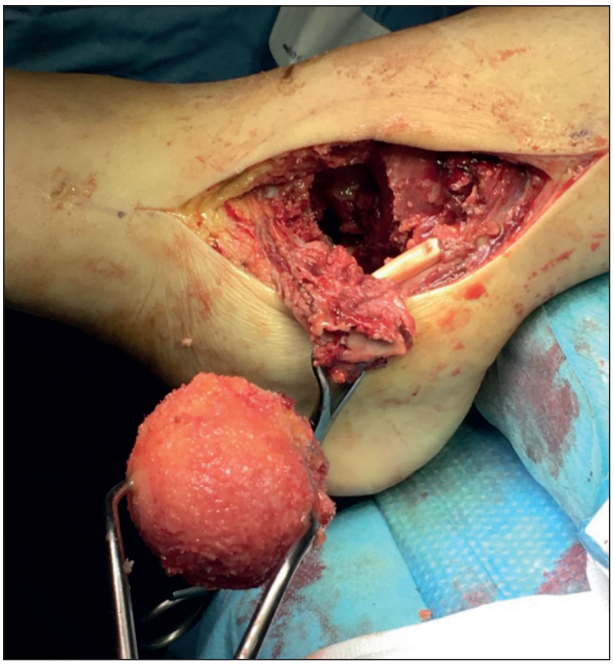

Figure 3. Femoral head before grafting

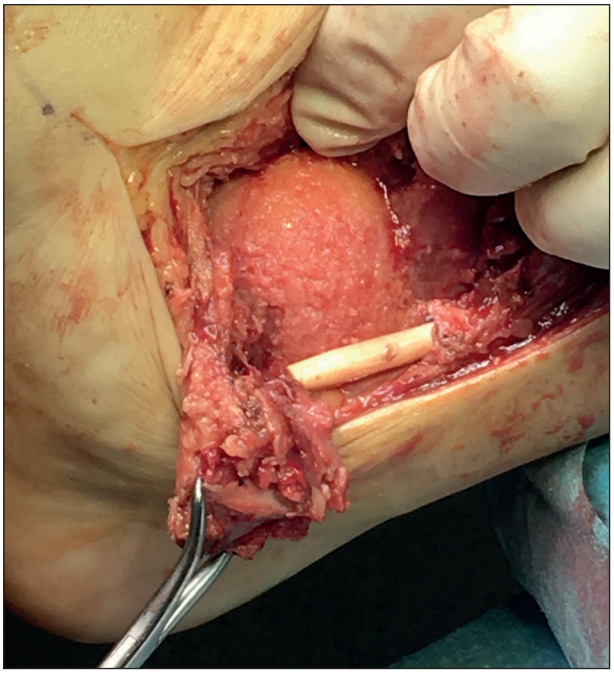

Figure 4. Final position of the graft

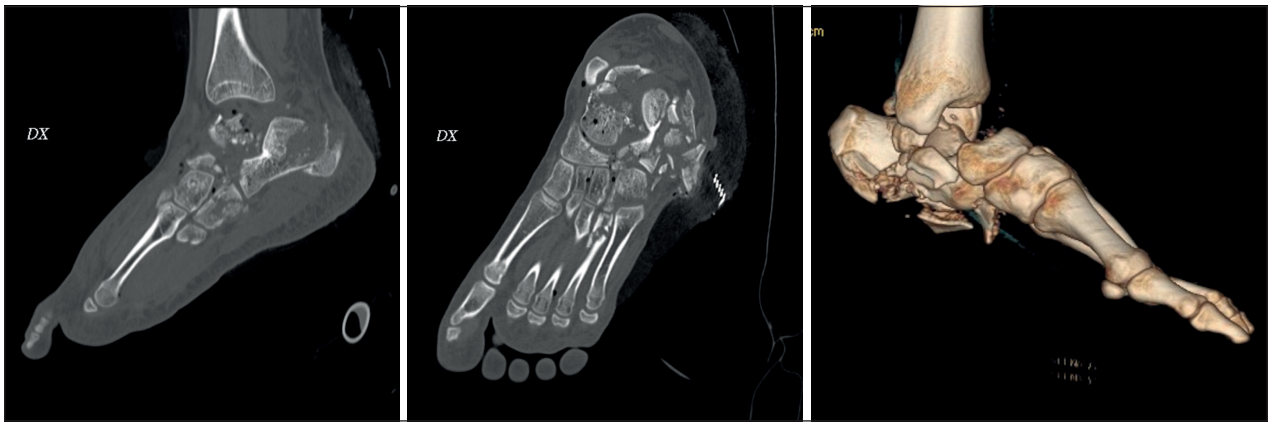

Figure 5. (A) Preoperative CT scan (Sagittal view), (B) Preoperative CT scan (Axial view), (C) Preoperative CT scan (3D Reconstruction)

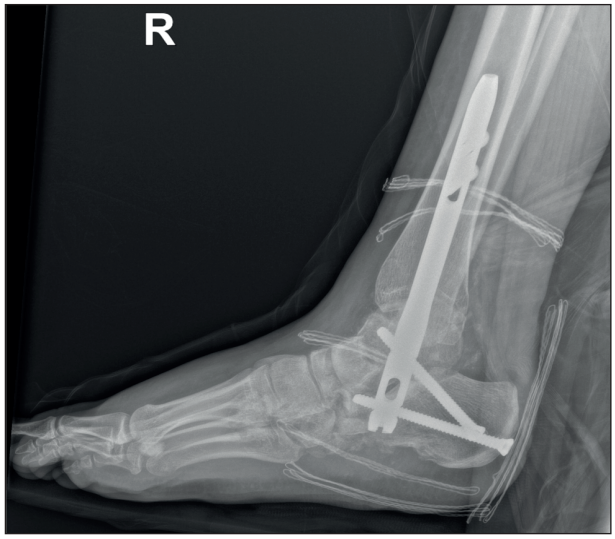

Figure 6. PostOperative X-Ray

The complicated traumatic injuries of right foot and ankle were treated with TTCA with placement of intramedullary nail and structural bone graft using the "*ball in basket"* technique immediately considering the severe comminuted fracture and the loss of bone stock.

The joint was reached with medial transmalleolar approach between the tendons of the tibialis anterior and posterior muscles. The talus bone showed evidence of significant comminution and severe loss of bone stock, whereas the thalamic calcaneal articular surface resulted intact. Therefore, one Valor™ (Wright Medical Group N.V. Memphis Tennessee - USA) nail (150/10 mm) and two screws (posteroanterior calcaneal and subtalar) were used following the "*ball in basket"* technique (Figure 6).

Patient performed clinical and radiographic follow-up plan of 30 months with bone reaction course monitoring until total assimilation of the bone graft and no complications were reported.

During the last clinical and radiographic follow-up evaluation at 30 months, a weight-bearing study was performed showing complete joint fusion and compliance of the normal ratio between the leg and foot axis (Figure 7 a/b).

Case 2

Female patient of 62 y/o with rheumatoid arthritis referred for severe bilateral rearfoot valgus deformity in status-post subtalar arthrodesis complicated by talar necrosis and consequent joint collapse (Figure 8 a/b).

The right joint was reached with lateral transmalleolar extended to the 4th metatarsus.

Therefore, one Valor™ (Wright Medical Group N.V. Memphis Tennessee - USA) nail (200/10 mm) and three screws (lateromedial, calcaneocuboid and talocalcaneal) were used following the "*ball in basket*" technique.

Clinical and radiographic follow-up plan of 4 months of patient was performed (Figure 9 a/b, Figure 10 a/b). During this time range, our assessment showed no evidence of mobilization of the fixation devices and presence of initial signs of osseointegration reaction with no signs of bone graft failure.

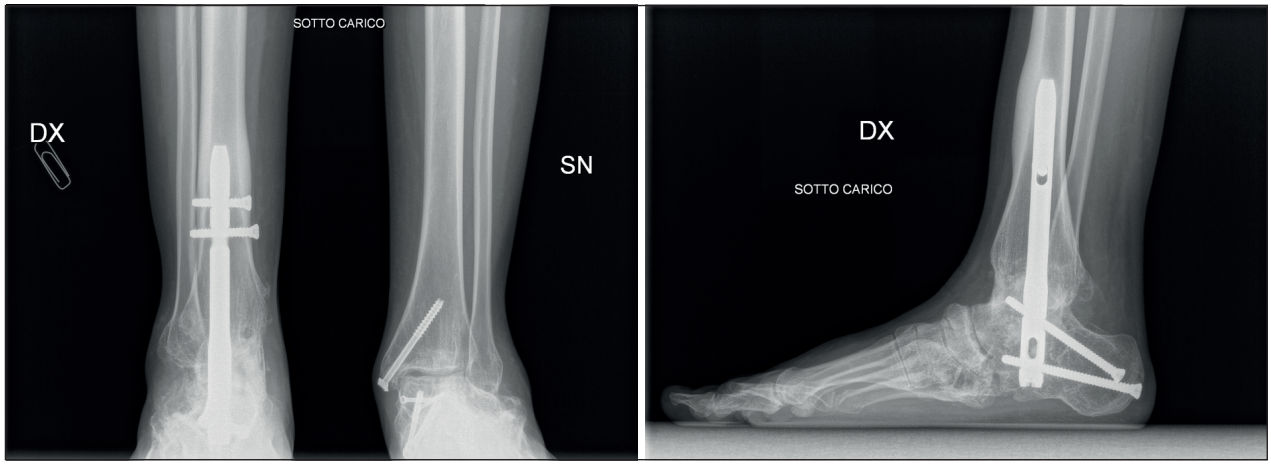

Figure 7. (A) X-Ray at 30 months follow-up, (B) X-Ray at 30 months follow-up

Figure 8. (A) Preoperative X-Ray AP ankle view), (B) Preoperative X-Ray (AP foot view)

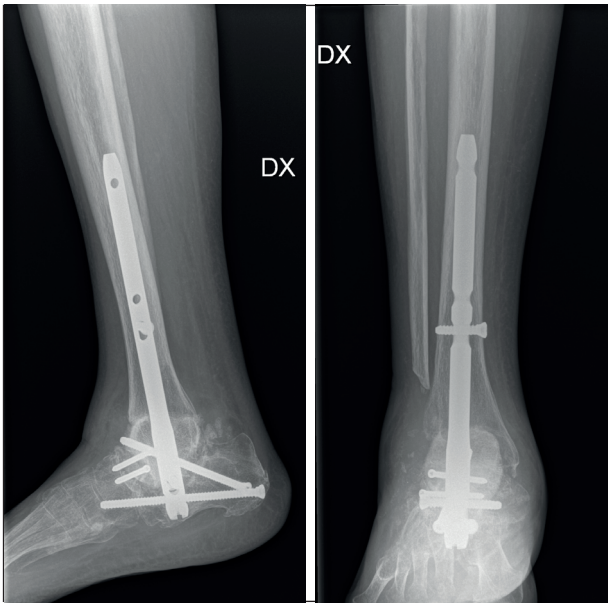

Figure 9. (A) 4 months follow-up X-Ray (Ankle Lateral view), (B) 4 months follow-up X-Ray (Ankle AP view)

Discussion

The *"ball in basket"* technique used in patient with different disorders (one case of status-post traumatic injuries and one case of previous surgical procedure failure) resulted flexible and reliable.

It represents a surgical method not simple to be performed and it requires a certain expertise of the surgeon, who must be familiar with both the anatomical

Figure 10. (A) Clinical presentation at 4 months follow-up (Right side correction compared to severe contralateral deformity), 4 months follow-up X-Ray (Ankle AP view), (B) Clinical presentation at 4 months follow-up (Right side correction compared to severe contralateral deformity)

region and the most adequate arthrodesis techniques. Furthermore, the surgeon must be skilled to prepare adequately the bone graft and the contact surfaces using tools not usually used in these body segments.

The concave reamers used for the preparation of the bone graft, in comparison with the use of the cutting tools, facilitate the reduction of the surface irregularities allowing the total removal of the residual cartilage, and provide the ideal features for an optimal osseointegration, as reported in literature (9).

The use of convex reamers for articular surfaces guarantees the removal of each joint cartilage residual, of fiber tissues and sclerotic bone, offering a bleeding layer of bone ready to accept the convex bone graft.

This surgical technique was named "ball in basket" specifically for the high congruence obtained with the preparation.

Our method ensures a higher sphericity of the bone graft with a better exposure of the spongious bone, compared to the technique proposed by Cuttica et al. (9) that uses BHR Smith & Nephew reamers type to prepare the bone graft.

In our opinion, a preoperative CT Scan study with 3D reconstruction is essential to obtain the most accurate result in order to use the proposed technique and provides the detection of a few fundamental parameters: the bone gap and the optimal diameter of the milling.

The femoral head from bone bank was selected for the *"ball in basket"* technique since it is easily available and can be prepared precisely.

Furthermore, in comparison with the autologous tissue, it provides a sufficient quantity of material, ensuring a reduction of the surgical time and a reduction of the postoperative pain.

Based on our clinical experience, the retrograde intramedullary nail was considered more suitable as stabilization system in this technique since, as reported in literature likewise, it results to be the tool that guarantees the best long-term results (5).

We recommend a long period of approximately 60 days with no weight-bearing, and afterwards a gradual recovery and regular free ambulation after 12 weeks due to the wide contact surfaces and the volume of the bone graft obtained with the femoral head.

The osseointegration process could furtherly be supported with the use of growth factors such as platelet-rich plasma (PRP) or mesenchymal stem cell (MSC), although these techniques require additional studies to evaluate the actual effectiveness in this specific application.

Conclusions

The *"ball in basket"* technique provides an optimal accuracy between the receiving site and the bone graft (a sphere in a cavity) and the stability of the bone surfaces, facilitating the introduction of the fixation device in order to obtain a stable construct with most excellent healing perspectives of the arthrodesis.

In our opinion, despite the reduced number of cases, the proposed technique has the features to ensure an optimal integration and stability of the bone graft, with a good recovery of the volumes and good final clinical outcomes.

The results that we obtained are encouraging, although a wider cohort of patients is crucial to determine the reliability and reproducibility of this technique in order to be recommended in selected cases with severe bone deficit diseases.

Conflict of interest: Each author declares that he or she has no commercial associations (e.g. consultancies, stock ownership, equity interest, patent/licensing arrangement etc.) that might pose a conflict of interest in connection with the submitted article

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