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Case report

Hemicalcaneal reconstruction with a 3D printed custom-made prosthesis after partial calcanectomy due to a malignant bone tumor

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Abstract. The malignant bone tumors of the calcaneus are extremely uncommon lesions. Surgical approach can consist in either an amputation or in a limb sparing procedure, depending on the width and the location of the neoplasm. Although several reconstructive options have been proposed to fulfill the bone defect in those cases that received a selective resection, to this date a consensus reconstructive approach is far from being established. Among the alternatives described in literature, 3D printed custom-made prostheses represent one of the most intriguing and promising reconstructive options. Herein, we report our experience of a spindle cell bone sarcoma of the calcaneus treated with selective resection of the anterior segment of the calcaneus and further reconstruction with a 3D printed custom-made prosthesis, based on patients' own anatomy. The posterior calcaneus and the insertion of the Achilles tendon were preserved. The resection was performed with wide margins and no major complication occurred through the intra-operative or post-operative intercourse. At her latest follow-up, our patient showed good functional results and was continuously disease free. Our outcomes therefore suggest that a partial prosthetic replacement of the anterior calcaneus with preservation of the Achilles insertion site may represent a safe and effective solution for cases that required the resection of the anterior calcaneus due to a malignant bone tumor. (www.actabiomedica.it)

Key words: sarcoma, custom made prosthesis, calcaneus

Introduction

The foot is a rare location for malignant bone tumors, since less than 4% of all malignant bone tumors involve this skeletal segment (1, 2). Due to such a low incidence, these tumors are associated with a high risk of delay in diagnosis. The recognition of calcaneal sarcomas is also not eased by the substantial absence of early pathognomonic clinical signs. Heel pain and localized ankle swelling, which are the most common presenting symptoms for calcaneal tumors, may lead to misdiagnoses. A wrong diagnosis could eventually cause inadequate treatments which may not solve the disease, but rather be responsible for its local spread (3). Such an error could have dramatic consequences for the patient, since amputation still represents the treatment of choice for the vast majority of cases with locally diffused and extracompartimental sarcomas of the foot. Although effective in eradicating the disease, amputation is inevitably associated with post-operative functional limitations and psycological issues that combined could significantly worsen patients' quality of life (4).

Cases with localized sarcomas of the foot, for their part, can be theoretically treated with a limb-sparing approach, consisting in the resection of the involved bone segment and a subsequent reconstruction (4).

In this article, we are reporting our experience with a case of bone sarcoma localized in the posterior

segment of the calcaneus who was treated with a resection limited to the anterior and central segment of the bone and consequential reconstruction with a 3D printed prosthesis.

Case report

This report has been performed in accordance with the ethical standards laid down in the 1964 Declaration of Helsinki and its later amendments. The case gave its content to the treatment and to the drafting of the article.

A 43 years-old female come to our attention due to persistent pain at her right foot, which had been increasing in frequency and magnitude through the previous months. Although the foot did not show swelling nor skin alterations, pain was associated with moderate functional limitations that limited some of patient's activities of daily living. Her functional score was 62/100 according to the AOFAS scoring system and 18/30 according to the MSTS scoring scale. The patient had already undergone an ultrasound which did not report any significant lesion of the soft tissues.

Further X-Rays, CT and MRI scans revealed an osteolytic lesion limited to the anterior right calcaneus (Fig. 1).

The insertion of the Achilles tendon, for its part, was still preserved and distant more than 2 cm from the posterior edge of the lesion. An FDG-PET testified that the lesion had an intense metabolic activity (SUV Max 5), but it was also a solitary lesion, since the exam did not highlight any other hypermetabolic spot in the whole patient's body. A biopsy established a histological diagnosis of Grade II Spindle Cell Sarcoma of the bone. Based on the preoperative images (CT, MRI, PET) a 3D printed custom-made hemi-calcaneal prosthesis was designed by Waldemar Link GmbH & Co., Hamburg, Germany.

In the operative theater, the patient was set on a radiolucent surgical table in lateral left position. We performed a lateral approach to the calcaneus using a *L shaped* skin incision. The peroneal tendons were detached at their insertion in order to allow a better visualization of the calcaneus and repertoire for the following reconstructive phase. Using a custom-made cutting jig and leaving intact the insertion of the Achilles tendon, we divided the posterior part of the

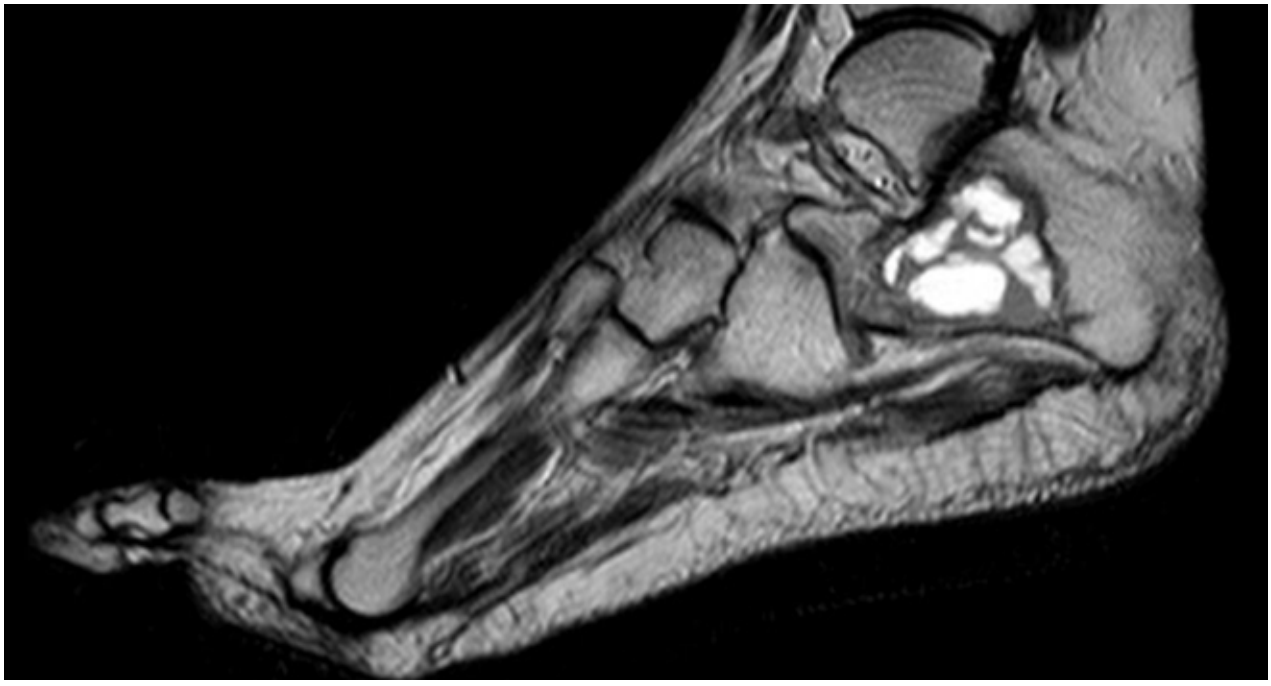

Figure 1. Pre-operative MRI image of out patient's right foot in T2-weighted frequency showing an osteolytic lesion.

calcaneus from its degenerated central and anterior segments. The anterior calcaneum was then disarticulated from talus and cuboid bone, allowing its en-bloc resection. Once resected, the specimen was delivered to our Pathological Anatomy division which confirmed the histological diagnosis and testified wide resection margins. The resulting bone defect was fulfilled with a 3D printed custom-made hemi-calcaneal prosthesis based on patient's own native anatomy and consisting of a Ti6AL4V alloy with a TrabecuLink structure on its bone contact surfaces (Waldemar Link GmbH & Co., Hamburg, Germany), the weight was 290 gr with a tensile strength of 860 N/mm^2 and a yield strength of 780 N/mm^2. Once in place, the prosthesis was fixed to what remained of the native calcaneus using appropriate spikes set on its posterior surface and a central metric threated M6 compression screw. The prosthesis was then stabilized to the talus with a 8 mm diameter TrabecuLink stem and fixed to the cuboid with a 6,5 mm diameter cancellous locking screw (Fig. 2).

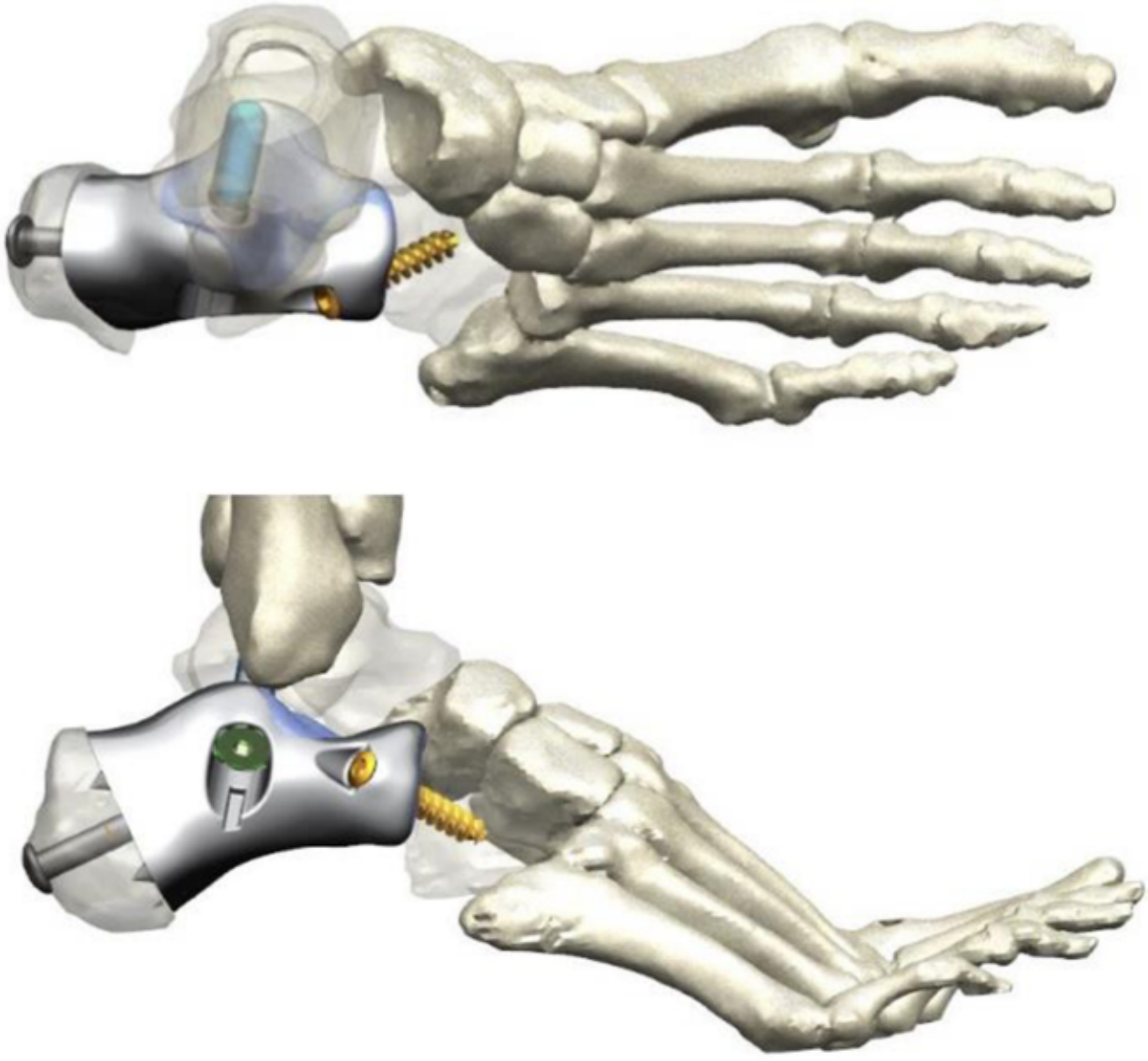

Figure 2. Graphic overview of our 3D Printed custom made hemi-calcaneal prosthesis.

The previously detached peroneal tendons were then reattached to the base of the 5th metatarsus using a 5mm Super Reevo mini suture anchor (Super Reevo ConMed, Utica, NY). Finally, intra-operative X-Rays were performed and the surgical access was sutured. At the end of the surgical procedure, a short leg splint with light ankle plantar flexion was applied and left in place for the following 3 weeks. Within 3 weeks of surgery the cast was removed and replaced with a short leg walker boot in neutral ankle position for the following 3 weeks. 1 month after surgery, the patient was allowed to start passive and light active mobilization of her right ankle and foot. In parallel, 30 days after the intervention she could start walking with progressive partial weight bearing on her right lower limb, reaching the full weight bearing within 12 weeks after surgery.

Our patient received periodic post-operative orthopedic outpatient visits and local X-Rays/ CT scans (Figs. 3, 4).

She also underwent periodical medical oncological evaluations, with systematic imaging (abdomen and chest CT scans) and nuclear medicine (FDG/PET) examinations in order to exclude the eventuality of metastatic lesions. In agreement with our medical oncologists, the patient did not undergo post-operative chemotherapy. At her latest follow-up, 16 months after surgery, our case did not suffer from any major intra-operative nor post-operative complication. She was continuously disease free (CDF), as no sign of local recurrence or metastatic lesions had been found through the post-operative intercourse. The imaging evidences testify good prosthesis integration, without any sign of fracture or loosening. The patient is now able to walk without limping and does not require any support. Surgery led to a significant improvement in patient's functional status, as testified by a clear increasement of her functional scores, compared to those she registered pre-operatively. Her final AOFAS score was 94/100, whereas the MSTS score was 30/30. These good functional outcomes, in association with pain disappearance, allowed our patient to come back to her previous activities of daily living.

Discussion

Calcaneus is the posterior part of the foot tripod and represents a pivotal structure for physiologic locomotion. A severe lack in calcaneal bone continuity inevitably causes hindfoot instability and gait disturbance. For these reasons, as last decades' improvements in imaging technologies, oncological treatments and surgical devices allowed the introduction of limb sparing surgery, orthopaedic oncologists began to orient their efforts towards calcanectomy and subsequent reconstruction rather than amputation or resection alone for cases who suffer from localized calcaneal malignant tumors (3-5).

The anatomical characteristics of the calcaneus make limb salvage possible in many cases, as only one aspect of the calcaneus is near major neurovascular structures. In case the tumor is confined to the calcaneus alone or even extends to the nearby connective tissues without involvement of other bone segments or noble structures, the removal of the calcaneus as a whole is considered sufficient to eradicate the disease. Always aiming for wide margins of resection, orthopedic surgeons are therefore often called to perform total calcanectomy along with the sacrifice of a share of the surrounding soft tissues that depends on the extension of the neoplasm (5). In our case, the setting and extension of the neoplasm at the moment of diagnosis allowed a partial resection of the calcaneus in place of a total calcanectomy. In fact, since the neoplasm was localized and involved only the anterior portion of the calcaneus, a segmentary resection could be considered an adequate treatment.

Although partial calcanectomy had already been proposed and described for the treatment of diabetic heel ulcers complicated with osteomyelitis, its use in the oncological field has been significantly limited so far (6). Furthermore, the vast majority of partial resections described in literature involved the posterior segment of the calcaneus. Its posterior segment, for its part, includes the insertion site for the Achilles tendon, playing a pivotal role in walking and maintaining the upright position. The sacrifice of the posterior part of the calcaneus therefore associates with the loss of an important anatomical structure that could cause significant post-operative limitations (7). This did not affect our case, since she did not require the resection of the posterior segment of the calcaneus nor the removal of the Achilles insertion.

Several solutions have been described in literature so far to reconstruct calcaneal bone defects after

Figure 3. Post-operative X-Ray of our patient's right foot, with the prosthetic implant in its site.

tumor resections. To this date, both bone grafts and prosthetic implants represent suitable options for target patients. In terms of biological options, both allografts and autografts have already been used and described with variable outcomes (8-11). Autografts, in particular, have been drawing increasing interest in recent years with papers produced by different authors around the world. Among them, Li et al (9)

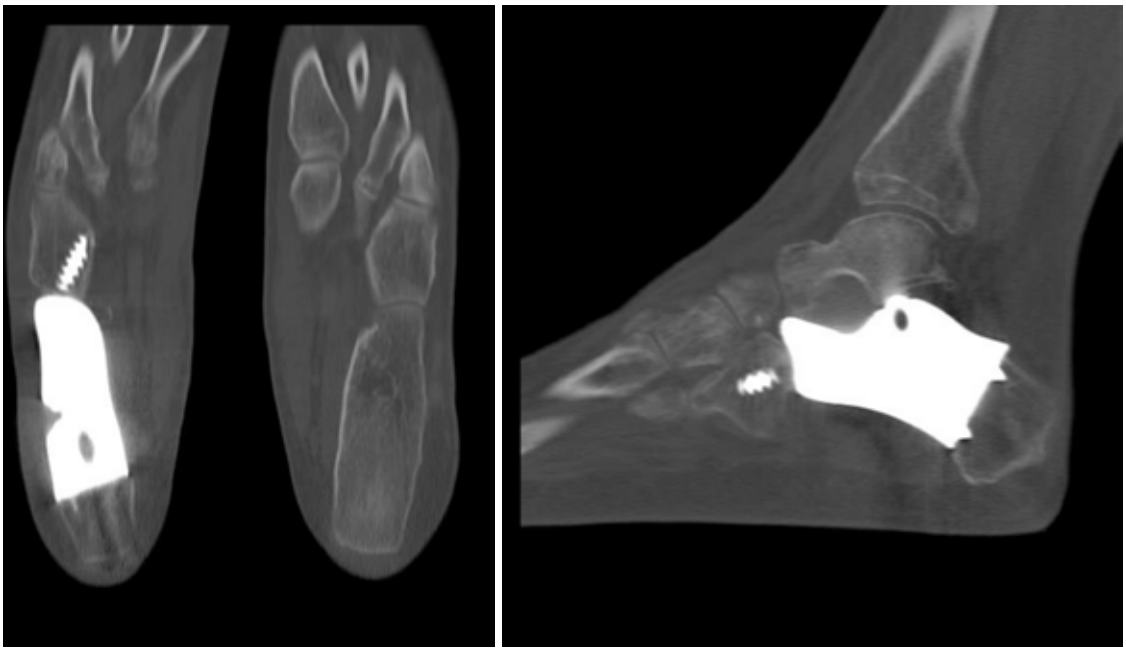

Figure 4. CT scan at 6 months showing a good positioning of the prosthesis and good integration with the remaining calcaneus.

reported their experience with the reconstruction of 5 calcanea with bony or osteocutaneous vascularized fibular grafts, obtaining good post-operative functional results (mean MSTS 83.2%). Similar outcomes using free vascularized fibulas have been recently obtained by Rosli et al in 2021, although their 2 cases were suffering of benign rather than malignant bone tumors (10). Another suitable donor site to harvest a functional bone autograft to replace calcaneus is represented by the iliac crest, as suggested by the work of Innocenti et al who obtained a mean post-operative MSTS score of 95% in their cohort of 4 cases (11). Despite these encouraging functional results, one of the main limitations of graft implants lies in the fact that they require a more or less extended period of forced immobilization in order to minimize the risk of non-union between the graft and the receiving site (8-11). While on one hand this period is necessary to allow the correct healing of the interface native bone - implant interface, on the other hand prolonged immobilization may cause fibrosis and surgical adhesions which might have a negative impact on patients' post-operative functionality. This risk is particularly high especially in adult patients whose functionality was still partially conserved at the moment of diagnosis like ours. Furthermore, in our case we had the chance to preserve the complex composed by the posterior part of the calcaneus and the insertion of the Achilles tendon, which allowed us to maintain the patient's own flexor apparatus in place and ready for the earlier stages of her rehabilitation protocol.

For these reasons, our reconstructive choice fell on a prosthetic implant in order to allow our patient an early rehabilitation and a quicker return to her previous functionality. The recent introduction of additive printing now allows the production and the implant of 3D printed prostheses that faithfully reproduce the size and shape of the native calcaneal bone (12). A number of case reports have already described the use of 3D printed custom-made implants, obtaining good functional results and acceptable complication rates (13-16). However, little has been written about partial replacements of the calcaneus with prosthetic implants and preservation of the insertional site for the Achilles tendon. Our experience testifies that such a solution can be performed without the onset of significant intra-operative or post-operative complications and can lead to excellent functional outcomes.

Few months after surgery, our case's treated foot could substantially match the performances of the contralateral one, allowing the return to her activities of daily living without significant restrictions.

In conclusion, our outcomes suggest that a partial prosthetic replacement of the anterior calcaneus with preservation of the Achilles insertion site may represent a safe and effective solution for cases that required the resection of the anterior calcaneus due to a malignant bone tumor. This reconstructive approach should therefore be taken into consideration among the other most common surgical techniques when oncologic surgeons are called to perform a reconstruction of the calcaneal bone.

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.

Consent Form for Case Reports: Written informed consent was obtained from the patient concerned.

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