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ORIGINAL RESEARCH ARTICLE

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Acellular dermal matrix and heel reconstruction: a new prospective

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ABSTRACT

Background: Heel reconstruction represents a challenge for all plastic surgeons due to the anatomical and functional features of this weight-bearing area. In the last decade a combined use of acellular dermal matrices and skin grafts has been proposed as a reliable and less invasive alternative for complex wound management; nevertheless only a few cases have been reported in the literature.
Methods: We describe the long-term outcome of 2 cases of severe degloving trauma of the plantar region with massive soft tissue defects of the foot, that underwent surgical reconstruction with artificial dermis and skin grafts. At the fifth year of follow-up, both patients underwent a clinical and a computerized gait analysis to study their functional outcomes and the kinematics of their gait.
Results: Both patients recovered functional ambulation and returned to their own work and vocational activities, showing a symmetric gait and parameters of upright posture fully comparable to normality.
Conclusions: Despite the initial concerns about the use of acellular dermal matrices and skin grafts for this kind of injury, they seem to be a simple and safe alternative for weight-bearing reconstruction of the degloved foot. The authors believe that the current study yields useful information and reassurance about their long-term reliability.

Keywords: Acellular dermal matrix, Degloving trauma, Gait analysis, Heel reconstruction, Skin graft

Introduction

Reconstruction of the weight-bearing surface of the foot presents challenging difficulties, due to the unique anatomical properties of the heel and its cushioning effect. It is accepted that restoration of heel function requires adequate reconstruction of its anatomical units including skin, subcutaneous tissue and bone. The “ideal” reconstruction should provide skin thick enough to resist bearing and bruising, bone hard enough to resist compression and a soft tissue layer between the skin and bone to absorb vibration (1). A great number of reconstructive options have been described, including cross-leg flaps, skin grafts, locoregional flaps and free flaps, each of them with their pros and cons (2, 3). Despite this large number of alternatives, no consensus exists, and an ideal flap for weight-bearing reconstruction has not been made clear (3). Furthermore, patients with significant hemodynamic changes caused by severe trauma, such as devastating crush avulsion injuries of the plantar surface, may be not suitable candidates for flap coverage. In those cases, harvesting tissue flaps through injured skin may jeopardize its survival, increasing the reconstructive problem (4). In recent decades, the use of acellular dermal matrices (ADMs) appears to be a useful alternative to vascularized flaps for extremity wounds with exposed tendons, bones and joints even in the compromised host. Regarding heel reconstruction, an accurate analysis of the current literature revealed that only a few studies exist describing small case series of combined use of ADMs and skin grafts for these kind of injuries, and none of them reported the functional results and gait analysis (5-10).

Materials and methods

Case presentation

We report the long-term functional analysis of 2 patients who underwent surgical reconstruction 5 years before by using ADMs and skin grafts after a severe crush injury with extensive deglovement of the plantar surface of the foot.

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Fig. 1 - Patient B: degloving injury of the right foot with extensive involvement of the heel and sole of the foot.

Fig. 2 - Patient B: after 5 years since reconstruction, showing a good anatomical contour of the plantar region without skin ulceration or breakdown.

Both of them were white male patients (ages 48 and 49 years old) presenting after a high-speed motorcycle accident (patient A) and work accident (patient B), respectively.

At admission, an adequate wound debridement to remove devitalized tissues was performed; after that a conservative management, consisting of negative pressure wound therapy (NPWT) and serial delayed excisions to obtain a clean and vascularized wound bed with proper coverage of exposed bone and tendons were adopted. Finally, both patients underwent surgical reconstruction with ADM (Integra®; Life Sciences, Plainsboro, NJ, USA) and subsequent split thickness skin grafts, and they completely healed after 58 and 63 days, respectively (Figs. 1-4). Five years later, both patients underwent a clinical and a computerized gait analysis to study their functional outcomes and the kinematics of their gaits.

Clinical and functional evolution

A small area (1 × 2 cm) of anesthesia in the central region of the reconstructed skin and a slightly reduced (<10°) ankle range of motion (RoM) were found. Patients recovered a functional ambulation reaching 4/5 for the Functional Ambulation Category (ambulation was independent on level surfaces and required supervision to negotiate unlevel or sand-like surfaces) (11). They returned to their own work and vocational activities, wearing orthopedic insoles with a cuff of shock-absorbing material at the heel level of the treated foot. A small skin ulceration was referred to by both patients and treated with conservative management.

Experimental session

Patients walked barefoot at natural cadence. Three gait and two posture trials (30s) with open (EO) and closed eyes (EC) were analyzed. Trajectories of markers in accordance with Ferrari et al (12), ground reaction forces (GRF) and plantar pressure distribution (TekScan System) were measured (13). Skin damage and ulcers were prevented through the patients orthopedic insoles.

Results

Gait

Spatiotemporal parameters (14) showed symmetry between legs for both patients.

Fig. 3 - Patient A: left foot after a degloving trauma of the heel with the acellular dermal matrix already applied.

Fig. 4 - Patient A: 5-year follow-up visit showing a satisfactory reconstruction of the heel.

Patient A

Spatiotemporal parameters were comparable to normative data (14) for both legs. Vertical force peak during the loading phase was slightly lower for the treated foot (97 ± 2.1% of body weight [%BW]) than for the contralateral one (105 ± 1.5%BW), and both were reduced with respect to normative data (14). Angular kinematics did not reveal any irregularities, with the exception of the dorsoplantar flexion: both feet showed a reduced dorsal flexion at the late stance and a reduced plantar flexion at the beginning of the swing. Analysis of pressure distribution showed overloads under the heel, the metatarsal heads and the toe (Fig. 5A). The overload area under the heel (Fig. 5A) was reduced for the treated foot.

Patient B

With respect to normative data (14), walking velocity was slightly reduced (0.7 ± 0.1 m/s vs. 1.24 ± 0.25 m/s), and the double support phases were prolonged for both legs (initial: 13.8 ± 2.7% and final: 16.2 ± 1.2% of gait cycle vs. 9.4 ± 2.3% for both phases). The loading phase was prolonged.

GRF during gait showed reduced peaks for both feet, in forward and rearward direction. During the foot flat phase, the load on both feet was higher (treated foot: 95 ± 2%BW, contralateral foot: 97 ± 1.4%BW) with respect to normative data (72 ± 11%BW). Pressure distribution showed overloads in the calcaneal area and under the second metatarsal head for the contralateral foot, while for the treated one, the overloads were localized in the whole plantar surface: under the heel, the lateral part of the plantar arch, the metatarsal heads and the hallux (Fig. 6A).

Posture

Posture parameters (15) were comparable between patients and with respect to normative data. For patient A, the center of pressure (CoP) trajectory during the EO trial for the treated foot was displaced anteriorly with respect to the contralateral one (Fig. 5B). For patient B, CoP trajectories were symmetric and centered under the plantar arch area (Fig. 6B).

Discussion and conclusions

In recent decades, with the advent of tissue engineering, the use of artificial dermal substitutes in the treatment of acute and chronic cutaneous injuries is becoming increasingly routine, particularly when a paucity of suitable uninjured cutaneous tissue is a challenging problem.

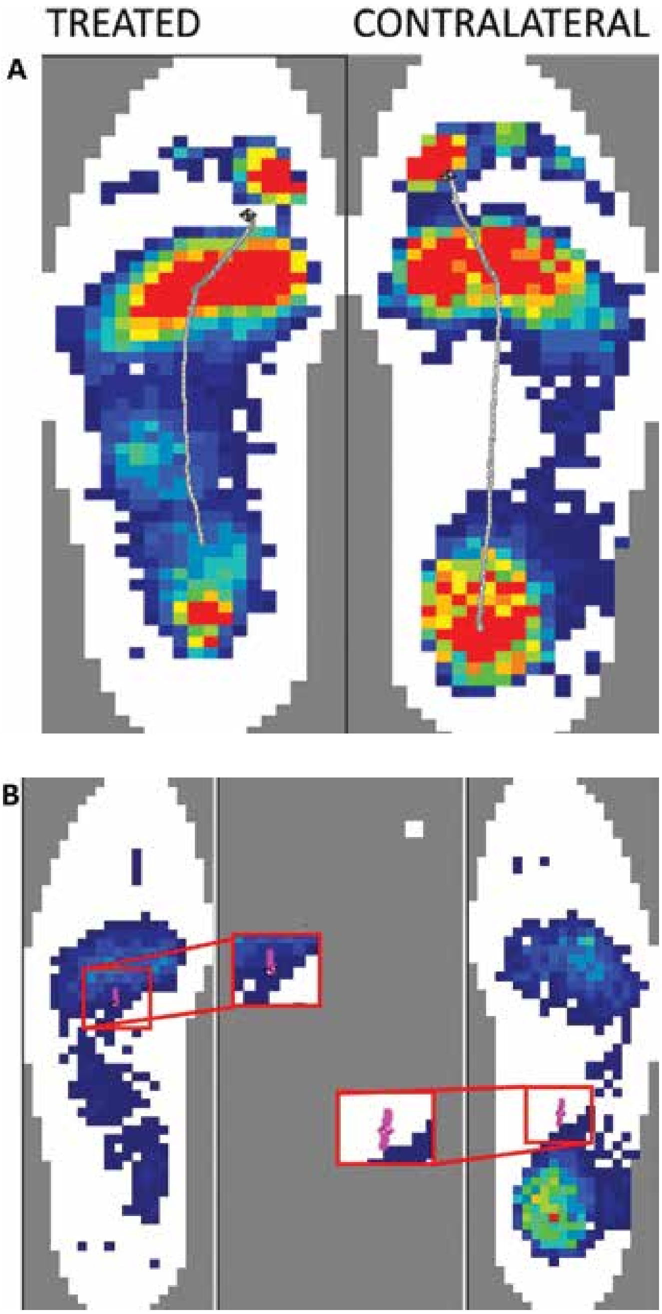

Fig. 5 - Pressure distribution for patient A during gait (**A**) and during posture (**B**). In the pictures, areas characterized by overloads are shown as red cells. The red box in (**B**) shows the center of pressure trajectory (magenta line).

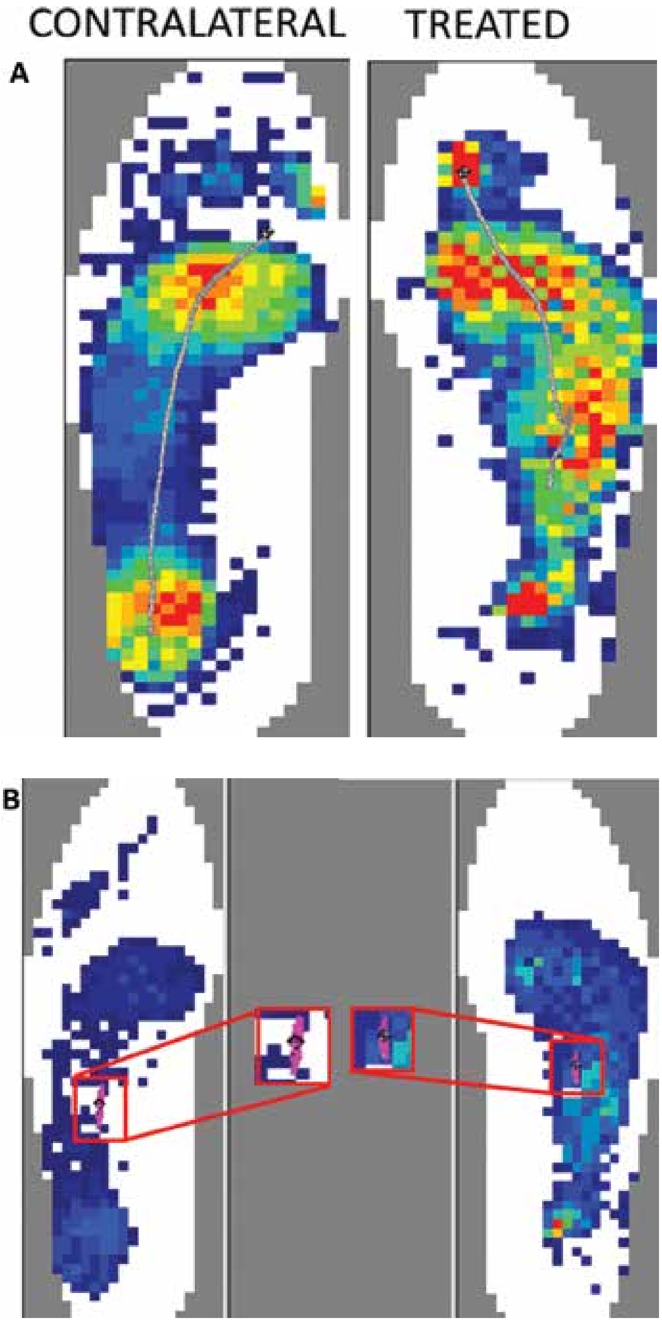

Fig. 6 - Pressure distribution for patient B during gait (**A**) and during posture (**B**). In the pictures, areas characterized by overloads are shown as red cells. The red box in (**B**) shows the center of pressure trajectory (magenta line).

Recently, a systematic review of the literature categorized 2 main types of skin substitutes: cell-based and non-cell-based skin substitutes. In the first group, several dermal substitutes such as Dermagraft, Apligraf, Hyalograft 3D, TheraSkin, Laserskin Autograft and OrCel are available on the market.

Dermagraft® (Advanced BioHealing Inc., La Jolla, CA, USA) is composed of allogeneic fetal fibroblasts seeded onto a bioabsorbable polyglactin matrix. Apligraf® (Organogenesis Inc., Canton, MA, USA) and OrCel® (Forticell Bioscience Inc., Englewood Cliffs, NJ, USA) are bilayered allogeneic constructs where neonatal cellular components (fibroblasts and keratinocytes) are cultured onto a hyaluronic acid and type I bovine collagen matrix, respectively. Hyalograft 3D and Laserskin Autograft (Fidia Advanced Biopolymers, Abano Terme, Italy) consist of autologous cultured fibroblasts and keratinocytes seeded onto a 3-dimensional hyaluronic acid–derived scaffold. Cells are isolated from a skin biopsy specimen taken from the patient. TheraSkin® (Soluble Systems, LLC, Newport

News, VA, USA) is a cryopreserved, human, cadaveric, split-thickness skin allograft which contains mature allogeneic dermal fibroblasts and epidermal keratinocytes, even if the rate of cells surviving after the cryopreservation process ranges from 0 to 60% (16, 17).

Among ADMs, most of the currently available clinical data focus on a few products. Integra® Dermal Regeneration Template (Life Sciences, Plainsboro, NJ, USA) is an acellular collagen (bovine)-chondroitin-6-sulphate (shark) porous sponge-like substitute which has found application in a wide variety of wounds (18). This layer is applied directly to the wound bed, acting as a scaffold for native capillary and cellular in-growth. The top layer is made of polysilaxone or silicone that prevents moisture evaporation from the underlying biologic layer.

GraftJacket® (Wright Medical Technology, Arlington, TN, USA) is an acellular tissue matrix manufactured from donated human cadaveric skin from US tissue banks. Donor samples are first screened for HIV, syphilis, human T-lymphotropic virus (HTLV; type 1 and 2), hepatitis B and C, as well as for any bacterial or fungal contamination. The allograft skin then undergoes histochemical processing that reduces antigenic responses by removing cells while leaving the basement membrane and collagen scaffold intact. The grafts are finally freeze-dried and rehydrated in normal saline intraoperatively before their placement in the recipient wound bed (19).

Matriderm® (Skin and Health Care AG, Billerbeck, Germany) is a 3-dimensional matrix composed of native, structurally intact collagen fibrils and elastin for supporting dermal regeneration. The collagen is obtained from bovine dermis and contains the dermal collagen types I, III and V. The alpha-elastin is obtained from bovine nuchal ligament by hydrolysis. The avoidance of chemical cross-linking of the collagen results in a matrix which is especially biocompatible. It can be applied concurrently with a split-thickness skin graft for the reconstruction of the lower extremities; thus, secondary surgery is not required (20, 21).

Despite these large numbers of tissue-engineered alternatives, only a few studies exist in the available literature, describing the use of ADM for heel reconstruction, and most of these are small case series. Furthermore, none of these studies reported the functional results and gait analysis (5-10).

In the present paper we describe the long-term functional analysis of 2 patients who had undergone surgical reconstruction using ADM and skin grafts 5 years before after a severe deglovement of the plantar surface of the foot. Both patients have shown an optimal recovery of gait function and social participation. The clinical findings correspond with largely normal gait and posture parameters of the gait analysis reports. However, patients' sensitivity disturbances and their new foot morphology explain the overload under the foot, as shown by the pressure distribution analysis, and result in a mild balance impairment, as the prolonged loading phase proved. Finally, the reduction of ankle RoM affects walking dynamics of the injured foot which shows a reduced peak in the vertical and fore-aft component of the GRF.

This case report is the first quantitative and objective description of clinical outcomes after heel reconstruction with ADMs and skin grafts of the foot, and it supports their long-term safety.

Disclosures

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Conflict of interest: None of the authors has any financial interest in any of the products, devices or drugs mentioned in this manuscript.

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