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Elimination of an extensive femoral soft-tissue defect using dermotension according to the Ilizarov technology

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The authors present a clinical case of a successful surgical treatment of a soft-tissue defect in a female patient with pelvic bone fractures and a severe extensive defect of the femoral soft tissues by using traction appliances fixed to the Ilizarov fixator. The method of transosseous osteosynthesis was used for treatment. Secondary sutures were applied after soft tissue necrectomy and the ligature ends were fixed to the mentioned traction appliances. Optimal rate and rhythm of distraction was produced in the process of dermotension. The traction of the wound ends towards each other started on the second day after surgery with the rate of 0.5 mm 6-8 times a day and continued 15 days. A 30-cm long juxtaposition of the wound edges was achieved. It enabled to use interrupted sutures. The integumentary tissue defect of the area over 1500 cm^2 was eliminated. The remaining wound areas that measured 5.0 cm × 10.0 cm and 8.0 cm × 12.0 cm in size were eliminated using the Tyrš dermoplasty. The patient's skin biomechanical condition was evaluated by acoustic velocimetry in order to prevent skin overstretching. Microcirculation of tissues in the wound and that of the stretched skin was controlled by ultrasound high-frequency Dopplerography. The healing of the wound soft-tissue defect using graduated dermotension is associated with redistribution of stresses in the integumentary tissue and with formation of its new mechano-biological status. Indirect signs of skin overstretching near the wound edges were not revealed. Three types of blood flow in the wound tissue were recorded with ultrasound Dopplerography: microcirculatory, arterial, and venous with a clear respiratory wave. The calculated index of differences near the wound edge and in the wound soft tissues varied from 5.0 to 23.0 relative units that is typical for an active granulation process. Good anatomic and functional results were achieved clinically. Static and locomotor functions of the lower limb recovered completely. The patient was satisfied with the cosmetic and functional results. The technique of dermotension using the Ilizarov fixator was used at the Center's clinic in 19 patients with open fractures of long bones that were accompanied with soft tissue defects of various sizes.

Keywords Dermotension, soft-tissue defect, wounds, femur, the Ilizarov technology, mechano-acoustic anisotropy, skin, microcirculation

INTRODUCTION

The increase in the severity of traffic injuries, frequent technogenic and natural disasters as well as local war conflicts has led to a sharp growth in the number of injured persons with open and gun-shot limb fractures accompanied by other tissue destruction. The success in their management depends much on the treatment of soft-tissue defects and wound healing [5]. However, due to the difficulties of extensive soft-tissue and skin defect closure such as an impairment of the local microcirculation, the defects remain unstitched in order to apply some type of soft tissue plasty at a later treatment stage or wait for wound repair by secondary intension. The treatment of such injuries may be possible with the use of the Ilizarov controlled transosseous osteosynthesis.

Several authors reported on a graduated skin tension (dermotension) under the traction forces that are produced with special appliances [4], or Kirschner wires [2] and regarded these ways as one of the efficient methods of skin defect closure. It was established experimentally that skin traction by more than 20 % results in a sharp reduction of the capillary flow and decrease in the number of perfused capillaries, their diameter and sinuosity. These changes cause the disturbance of oxygen transportation to the tissues [10]. Graduated traction activates dermogenesis and tissue growth stimulation [4] that is accompanied by an increase in the capillary flow due to a 20-fold or even higher increase in the density of capillaries (ratio of capillaries to tissue) [9].

The optimal rate and rhythm of distraction is of primary importance by application of dermotension in order to prevent the disturbance in microcirculation. Therefore, the biomechanical condition of the skin under stretching should be well checked. Along with the clinical manifestations (pain, skin paleness) laser flowmetry may be used for control, and namely, the parameter of microcirculation flow reduction by more than two perfusion units that indicates that the graduated juxtaoposition of the wound edges should be stopped [1]. The combination of such methods of an express diagnosis allows for prognosis of possible development of the conditions close to the limit of skin deformation by tension, and for correction of treatment tactics.

Objective – to present a clinical case of operative treatment of an extensive soft-tissue defect in the lower limb with a special traction appliance and the results of a diagnostic monitoring of tension distribution and tissue perfusion of the skin close to the wound area during the course of treatment.

MATERIALS AND METHODS

The method of dermotension with the Ilizarov fixator was used in the Center's clinic in 19 patients (age range: 13-60 years) who sustained open long bone fractures associated with soft-tissue defects of various sizes. We present a description of one clinical case of a 37-year old female patient (medical record № 36277) who sustained

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a direct massive trauma that resulted in pelvic fractures and crushing of the thigh tissues that caused an extensive soft-tissue defect on the right thigh and analyze the outcome of her operative treatment. There was a trapezoid wound on the lateral side of the right thigh that measured 56 × 25 × 15 cm on the surface, and was from 3 to 6 cm deep. The wound had necrotic areas in the muscles, fascia, and subcutaneous fat (**Fig. 1a**).

Treatment was conducted with the use of transosseous osteosynthesis of the femur. Necrectomy of the soft tissues was performed and secondary sutures were applied. The ends of the suture material were fixed in traction appliances attached to the Ilizarov fixator in order to gradually manage the soft-tissue defect (**Fig. 1b**). Traction of the wound edges towards each other started on day 2 postoperatively with the rate of 0.5 mm × 6 (8) steps and continued 15 days. A 30-cm long juxtaposition of the wound edges was achieved, so it was possible to apply knot stitching.

The objective checking of the character of tension distribution in the areas close to the wound was performed with the study of anisotropic mechano-acoustic skin features that allows for indirect assessment of the skin deformation by tension [6]. The velocity of surface acoustic wave distribution (VSAW, m/sec) in the longitudinal (parallel to the limb axis), transverse (90°) directions and at 45° and 135° in regard to the limb axis was defined. A skin acoustic analyzer was used for this purpose (acoustic skin analyzer ASA-4, Moscow-Belgrade). The areas studied were 3 to 5 cm distanced from the wound surface along the anterolateral (four zones) and posterolateral surface of the thigh (**Fig. 1c**).

Microcirculation was evaluated basing on the analysis of the linear (Vas, cm/sec) and volumetric velocity (Qs, ml/sec) of the capillary flow in the wound soft tissues with the ultrasound high-velocity Dopplerography [7] using a computerized diagnostic device Minimax-Doppler K (Russia). A high-frequency sensor (25 Mhz) was used. Microvessels located down to 10-mm deepness were detected. The diameter of the operational part of the sensor was 1.5 mm. Measurements were performed in the following points: uninjured skin of the contralateral segment (point 1), injured limb skin areas under tensile forces at a 10-cm distance from the wound (point 2), exposed soft tissues of the wound (point 3), and the area of marginal epithelisation of the wound (point 4).

The study was conducted upon approval of the ethics board of the RISC RTO. The aims and the study methods were explained to the patient, and she gave her informed consent.

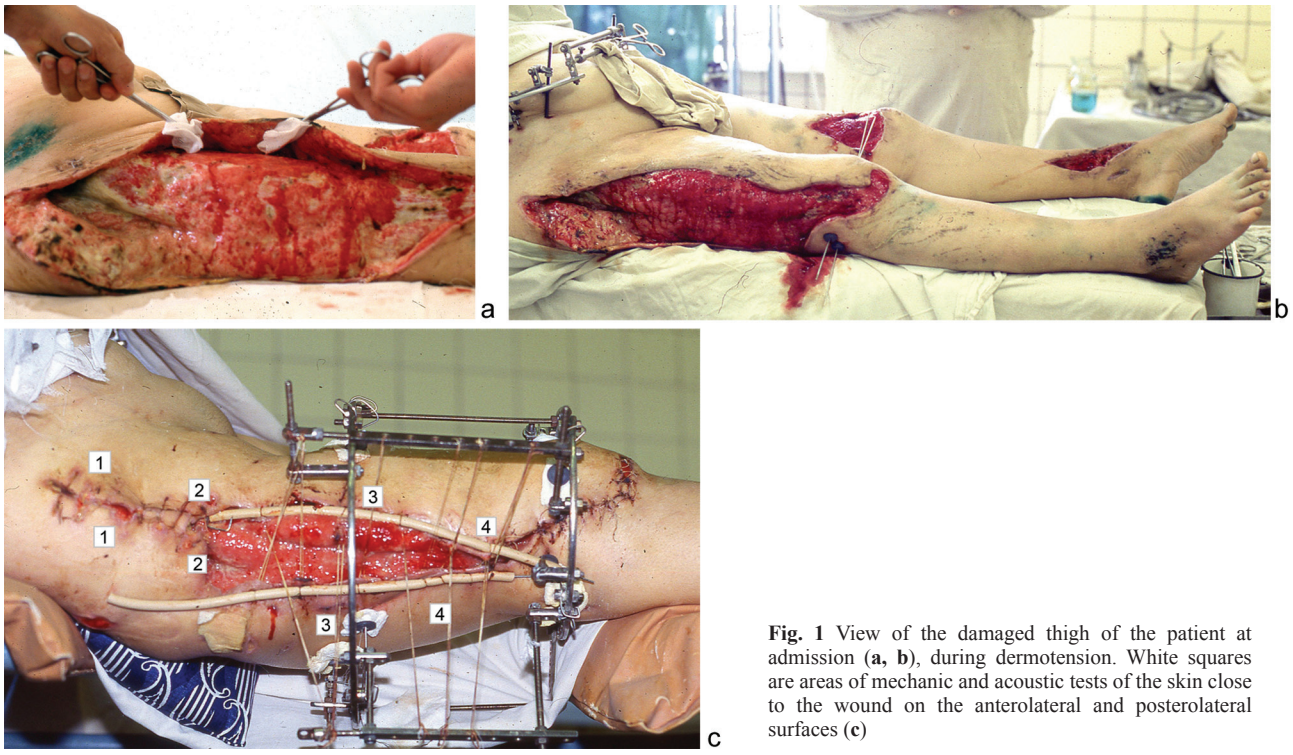

Fig. 1 View of the damaged thigh of the patient at admission (**a, b**), during dermotension. White squares are areas of mechanic and acoustic tests of the skin close to the wound on the anterolateral and posterolateral surfaces (**c**)

RESULTS

Due to an extensive soft-tissue defect in the lower limb and a pelvic fracture, the method of Ilizarov transosseous osteosynthesis was chosen for treatment (**Fig. 1**) along with nectrectomy, secondary sutures and their ligature to the traction units that were attached to the Ilizarov apparatus. Traction that continued 15 days allowed approximation of the wound edges on the extension of 30 cm and knot stitching upon juxtaoposition. As a result, the soft-tissue defect area of more than 1500 cm^2 was bridged. The remaining wound areas that measured 5.0x10.0 cm and 8.0×12.0 cm were treated by the Tyrš dermoplasty. Clinical anatomic and functional outcomes were good. Static and locomotor functions recovered. At a 1-year follow-up, the patient had no complains. She continues working and is satisfied with the outcome and esthetics of the limb (**Fig. 2**).

Fig. 2 Patient's photo at a 1-year follow-up

Mechano-acoustic testing of the skin located close to the defect (fig. 1, b) revealed an increase in the VSAW both in the longitudinal and transverse directions during dermotension. The construction of "acoustic fields" at the ends of VSAW velocity vectors in four directions enabled to obtain the images of spatial distribution of tensions in the areas studied (**Fig. 3**).

Prior to traction, the shape of AF in the skin of the second and fourth areas was different, elliptical and rounded, respectively. On the stage of dermotension, AF shape in the areas mentioned was similar, that is round. It was close to elliptical with a large axis by diagonal orientation (135°) after treatment completion. It proves a dynamic modification of mechano-acoustic anisotropy in the skin areas under stretching during the process of dermotension and after its completion. There was not any considerable growth in the VSAW during dermotension in all the skin areas studied on the anterolateral and posterolateral surfaces. The healing of the wound soft-tissue defect with the use of graduated dermotension is accompanied by the redistribution of tension forces in the integument tissue and formation of its new mechano-biological condition; a different configuration of the acoustic fields relative to the initial one was observed (**Fig. 3 2A-2C; 4A-4C**).

According to the findings of ultrasound Dopplergraphy that studied the microcirculation in the wound tissues, three types of blood flow were recorded in dependence to the location area: microcirculatory, arterial, and venous with a clear respiratory wave (**Fig. 4a**). In the uninjured skin integument that was under distraction forces a microcirculatory type of the Dopplerogram curve was recorded. Its spectrum was clear and was not associated with respiration. The calculated parameters of blood flow velocity were increased by 250–350 %, with the maximum values recorded in the proximity to traction units (**Fig. 4b**).

At the distance of 10 cm from the traction units, the skin capillary blood flow remained increased and featured a prevalent arterial component (**Fig. 4c**). The calculated index of blood flow variation (ratio of blood flow values Vas at the wound edge to the one in the wound soft tissues) was higher than 1.0. It varied from 5.0 up to 23.0 relative units that is characteristic of an active granulation process [3]. The growth in the values of the capillary blood flow by graduated skin stretching reveals favourable adequate conditions for reparative regeneration of the skin. It was shown in the earlier experimental works that the mitotic activity increases under the effect of graduated skin traction [8]. Moreover, dermogenesis is activated and tissue growth is stimulated [4].

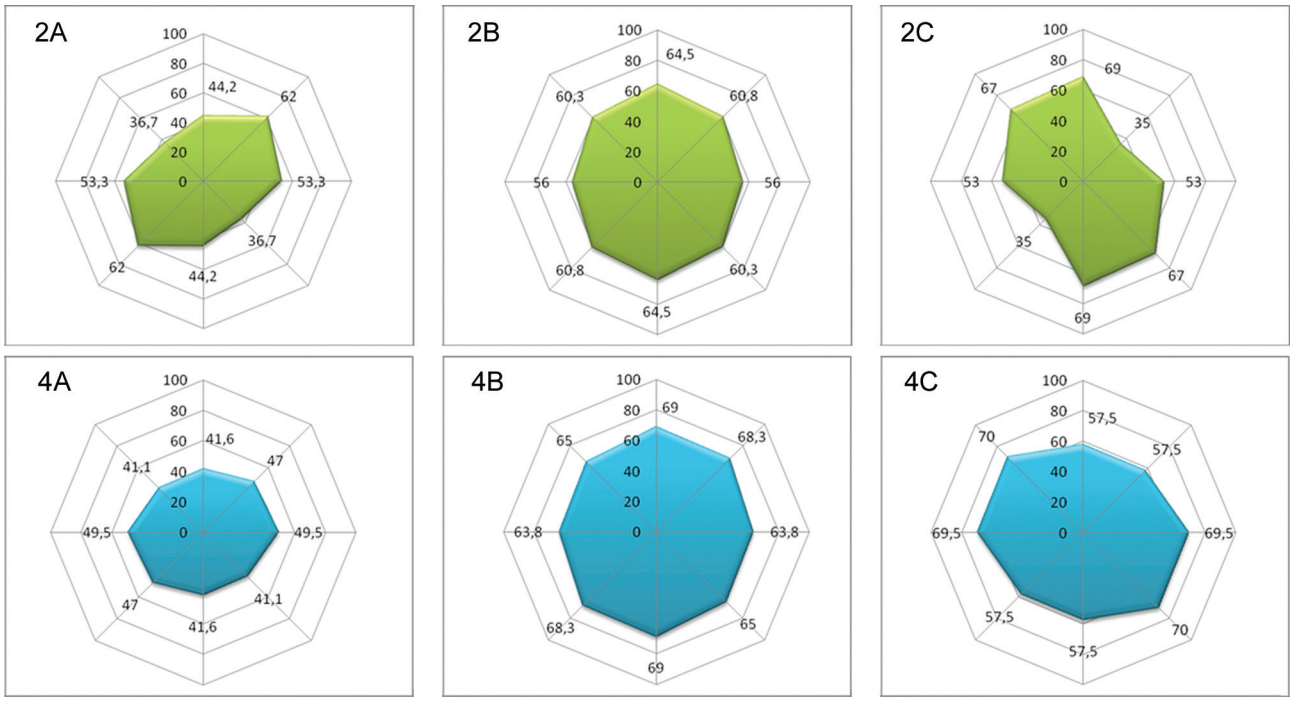

Fig. 3 Diagrams of spatial distribution of tension (mechano-acoustic fields) in the skin of tested areas 2 and 4 on the anterolateral surface of the injured thigh close to the wound. Prior to application of the traction appliance (**2A, 4A**). During dermotension (**2B, 4B**). Upon treatment completion (**2C, 4C**). Velocity of surface acoustic wave distribution (acoustic anisotropy) in the skin is shown in longitudinal, transverse and diagonal (at 45° and 135°) directions relative to the longitudinal axis of the limb

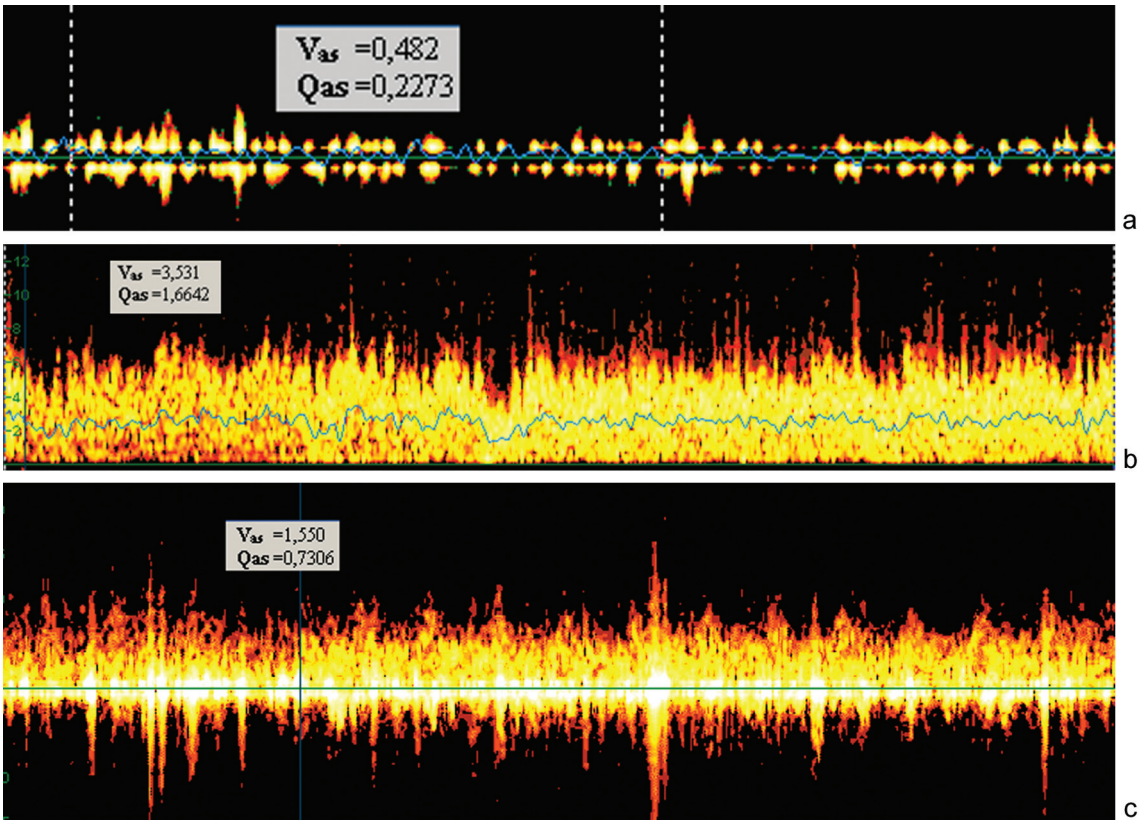

Fig. 4 Dopplergrams of soft tissue perfusion. Intact limb (corresponds to the norm), Vas 0.1-0.8 cm/sec (**a**). Close to the traction units under distraction force, the capillary flow is increased by 350 % relative to the norm, Vas=3.53 cm/sec (**b**). Areas at the distance of 10 cm from the traction units, Vas 1.5 cm/sec (**c**). Capillary flow with a prevailing arterial component is increased by 50 % relative to the norm

CONCLUSIONS

The use of a low traumatic method of graduated skin traction with special appliances to the Ilizarov apparatus allowed for control of stretching forces by management of an extensive soft-tissue defect in a limb segment. Traumatic and costly plasty with free or non-free soft-tissue complexes that do not survive in one third of cases and leave an esthetic defect on the donor site was not used. The biomechanical test of the skin with the use of a minisensor in an on-line mode is an objective method of control of the tension distribution in the integument tissues at the edge of the wound surface during all stages of treatment. The transition of the skin into a state of tensile deformation by dermotension using the Ilizarov technology is accompanied by a two- or three-fold increase in the capillary flow. It means that the microcirculation is not disturbed. The combined biomechanical and microcirculatory monitoring enables to follow the course and character of limb soft-tissue defect healing. Clinical examination and findings of the mechano-acoustic distribution of tension in the skin close to the wound and microcirculation parameters during dermotension and upon wound defect healing allowed us to conclude that there were no disorders in the adaptive and compensatory processes in the tissues of the injured limb. Therefore, the use of the dermotension technique described above in combination with the monitoring of skin microcirculation and mechano-acoustic state enables to solve the task of an extensive soft-tissue defect closure at one stage without complications and reduce the period of anatomic and functional recovery of the injured limb.

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