Review

Clinical treatment and research of hand burn scar rehabilitation

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Received: October 29, 2021; Accepted: November 10, 2021

A scar is a general term for the appearance and pathological changes of skin tissue caused by various wounds, and it is an inevitable product of the natural repair process of human wounds[1]. Wounds deep into the dermis and subcutaneous tissue inevitably lead to scar repair, which is an imperfect replacement for the pre-injury tissue. Scars, caused by trauma, would not only affect the outward appearance and function. They could also affect the psychological state and social compatibility of patients to varying degrees[2]. Among all traumatic scars, burn scars have a severer impact on patients due to the different severity of the burn. The hand is an important organ for human survival, labour and social contact. Because of its exposed pattern, it becomes one of the most easily affected organs by burns. Due to the particularity of hand skin and subcutaneous tissue structure, scar hyperplasia and contracture are easy to occur after a deep burn on the back of the hand. In severe cases, a "claw hand", affecting the quality of life of patients[3], can be formed.

The severity of hand burn scars has raised concerns about treat[1]ment and prevention. This article reviews the clinical application and research of the prevention and treatment of scar hyperplasia in recent years.

1. Early scar excision and skin transplantation

Large-scale scar formation and scar contracture of the hand could be prevented by early-stage eschar removing after burns and free transplantation of split thickness skin [4]. However, for some scars formed after the healing of deep second-degree burns on the back of the hand, it is hard to gain positive outcomes by the above operation. For compensation, functional rehabilitation is suggested before and after the surgery. Aghajanzade [5] et al. observed the recovery of daily functions among hand-scar patients with occupational therapy (3 session × 8 weeks). They believe that surgery combined with this type of task-oriented training had an obviously positive impact on patients with scar contracture after hand burn. This combination could also improve their joint mobility and quality of life.

2. Local pressure

For non-surgical healing of hand scars, or linear hypertrophic scars after surgical repair, wear elastic compression gloves to inhibit scar hyperplasia and promote scar maturation[6]. External pressure can reduce the blood flow and inflammatory reaction in the scar area, inhibit the proliferation and function of Fibroblast in muscle, reduce

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collagen synthesis, increase its decomposition, or rearrange collagen fibres so that the scar becomes flat and lighter in colour. Johnson[7] et al. conducted a questionnaire survey and found that 41% of burn scars were pressurized for 23-24 hours a day. Furthermore, the range of motion (ROM) improved with discomfort decreased. These help pressure gloves become potential management.

Li [8] et al. implemented sequential pressure rehabilitation combined with nursing intervention for patients with hand burn scar formation for one month. Compared with the control group, the above experimental group presents significant improvements in rehabilitation status of hand function, patients' satisfaction with rehabilitation status. Anxiety, depression, and the occurrence of complications were reduced as well. In summary, sequential pressure rehabilitation combined with nursing intervention can restore the hand function of patients with hand burn scars with sufficient safety.

Shi [9] et al. combined the application of customized pressure gloves and pressure pads in the treatment of hand burn scar and found that after six months of treatment, the effect of controlling scar hyperplasia and secondary deformity was better than that of the treatment group of pressure gloves alone, and the appearance of the treatment group was significantly improved.

However, when applying compression gloves for further treatment, additional factors, such as griping capacity, glove durability, and comfort, should be under consideration as well [10].

3. Topical medication for hypertrophic scar

Drugs that can inhibit scar include silicone glue, corticosteroid-ointment, angiotensin-converting enzyme inhibitor, plant extracts including onion extract, asiaticoside and aloe, immunosuppressor , vitamin E, retinoic acid, and other antioxidant drugs. Some anti-tumour drugs and some Traditional Chinese medicine would also present certain effects.

3.1 Silicone Glue Silicone is a synthetic polymer whose properties depend on the length and degree of cross-linking of its polymer chain. It can be a fluid, transparent gel or rubber-like substance. The existing silicone gel products, aiming at reducing scar hyperplasia and improving the scar in the shape of silicone rubber, are silicone gel spray and silicone gel strips. Their mechanisms of action are as follows: (1) fully applying silicone to stick on the skin, can reduce the skin moisture loss and rebuild the corneous hydration layer. These are not only beneficial to the stability of mast cells and inhibiting the release of pro-inflammatory factors. It can also reduce the secretion of pro-inflammatory factors in dehydrated glial cells after trauma, stabilize the successful balance of the epidermal barrier layer, and inhibit the proliferation of fibroblasts and collagen deposition. (2) Silicone directly stabilizes local temperature, oxygen partial pressure and mechanical pressure to create a hydrated and closed environment, which weakens the activity of new capillaries and affects the activation of related signalling pathways related to scar formation[11]. (3) Silicone gel tablets could increase the expression of basic fibroblast growth factor (bFGF) by decreasing the expression of TGF-β1 and platelet-activated growth factor (PDGF) in skin tissues. TGF-β1 and PDGF down-regulation is beneficial to prevent scar formation. The up-regulation of bFGF can prevent scarring by inhibiting the synthesis of hydroxyproline and then collagen. (4) small molecular silicone oil can penetrate tissues and inhibit the proliferation of fibroblasts, subsequently inhibiting the activity of fibroblasts. Furthermore, studies have also shown that the static electricity generated by the membrane between silicone dressings and wound tissue can also prevent scar formation[12].

3.2 Corticosteroid ointment: The anti-inflammatory effect of these drugs can inhibit fibroblast proliferation and collagen regeneration, and inhibit the expression of (TGF-β1), TGF-β2 and collagen in keratinocytes[13].

3.3 Angiotensin-converting enzyme inhibitors Inhibit fibroblast proliferation, inhibit TGF-β/Smad signalling pathway, and down-regulate the expression of type I and III collagen[14].

3.4 Plant extracts including onion extract, Asiaticoside and aloe have stable mast cells, antibacterial, inhibit fibroblast proliferation, promote extracellular matrix degradation, fibrinolysis and inhibit the TGF-β/Smad signalling pathway.Inhibition of growth differentiation factor-9 (GDF-9)/mitogen-activated protein kinase (MAPK) /Smad signaling pathway.Increased wound tissue moisture, decreased neovascularization activity, inhibit matrix metalloproteinase (MMP) -9 mediated inflammatory response[15]-[16].

3.5 Immunosuppressant drugs, such as imiquimod and tacrolimus, can reduce the secretion of IL-4 and IL-5 and increase the secretion of interferon γ (IFN-γ).

3.6 Vitamin E and retinoic acid have antioxidant effects. In addition, they could also maintain the stability of biofilm, inhibit fibroblast proliferation and collagen synthesis, and stimulate the secretion of basic fibroblast growth factor (bFGF).

3.7 Finally, mitomycin C, tamoxifen, Salvia miltiorrhiza, and Chuangongazine, have anti-scar effects as well.

4. Extracorporeal shock wave therapy

Extracorporeal shock wave therapy (ESWT) instrument presents a kind of pressure wave produced by a series of sudden energy releases, which convert pneumatic pulse sound waves into precise ballistic shock waves and promote a biological effect on local tissues through conduction of physical medium[17]. It has the characteristics of instant pressure increase and pressure conduction. The extracorporeal shock wave has the advantages of slight injury, replacement of surgical therapies, no anaesthesia, short treating duration, low risk, no special postoperative treatment, rapid postoperative recovery and low cost[18]. Lee[19] et al. applied a randomized control trial with 48 patients (split thickness skin graft on the back of the hand). The experimental group was treated with 0.05-0.30mJ/mm^2 low-energy flow density shock wave with conventional therapy. After treatment, scar thickness, erythema, and sebum increased. These studies show that extracorporeal shock wave therapy is beneficial in improving scar contracture, oedema, and limb pain.

5. Continuous passive Exercise rehabilitation

Continuous passive movement (CPM) rehabilitation therapy is one type of physical therapy that enables bedridden patients to stretch, flex and abduct their limbs in a full range of passive movements. The equipment based on the same principle is called a CPM machine, which guides the human body to do repetitive training with a linear sliding table or reducer. Speed could be adjusted appropriately according to the requirement of patients. This therapy aims to joint spasticity, pain, muscle atrophy, prevent an insufficient range of motion, and promote joint function recovery. Additionally, tendon and ligament adhesion in bedridden patients which are conducive to early rehabilitation of joint function could be avoided. It is an advised therapy for burn since its characteristics of convenient speed regulation, safety, reliability, accurate time reading, adjustable angle, easy to carry, visible exercise mileage, and so on[20].

Zhao[21] et al. conducted a retrospective cohort study on 43 patients with scar contracture after deep second degree to full thickness degree burns on the back of hands. This study found that patients who underwent combining rehabilitation, which is pressure gloves and functional training and CPM system, had significantly improved the range of motion of hand joints and hand scars compared with pressure gloves alone or combined functional training with pressure gloves. It is suggested that for the patients with hand burn scars, the full cycle rehabilitation plan should be formulated in a targeted and predictable way, and the rational use of modern rehabilitation instruments can accelerate the functional recovery, shorten the treatment period, improve the quality of life, and enable the patients to return to society as soon as possible.

6. Standardized rehabilitation treatment

After skin graft surgery, early rehabilitation was performed first using splints, braces, ROM training (passive exercise, active exercise, and night splint fixation alternately)[22]. There are two types of splint, rest splint and active splint. The former one usually is applied at night. It keeps the wrist extended for 30°, metacarpophalangeal joint flexion 50°-70°, interphalangeal joint full-extension, thumb extension abduction. Active splints are worn during the day to build muscle strength and facilitate movement. These two types of splints are commonly made of plastic materials for personal customization. This treatment can effectively prevent the claw hand deformity caused by hyperextension of the metacarpophalangeal joint, abnormal flexion of the interphalangeal joint and flexion of thumb adduction. In one study, Barillo[23] et al. reveal that 89% of patients had a full range of hand motion of 220.6°at discharge after skin grafting, with a 229.9°ROM three months after injury. Handgrip strength reached 60.8 LBS at discharge and increased to 66 LBS six months after leaving the hospital.

Yi[25] et al. applied protective splint, dynamic splint and palm-finger flexion gloves to 20 patients with hand burns at different stages. After 3 months, the ROM of all the joints of burned hands increased, and no typical hand deformity such as claw hand appeared. Functional assessment of the upper limbs and hands showed a significant increase. In summary, using different splints at different times after-burn could prevent and treat hand joint spasticity and deformity caused by burn scar contracture and improve hand function.

Wang[25] et al. used orthopaedic devices made of plastic splints for hand function rehabilitation of children with burns. After three months of treatment, the scar forms, hand functions and daily capacity were significantly improved. Richard [26]et al. found that in ROM training, the position of adjacent joints could influence the result. For example, there is a significant difference in the skin movements amount of elbow joints in extension and flexion positions ($P < 0.001$). It suggests that different positions of adjacent joints (joint-by-joint) can be taken into account for burn rehabilitation.

Zhu[27] et al. treated a group of hand burn patients with nylon tape, flexion tape and velcro tape for three months based on conventional hand function training and wearing pressure gloves two weeks after wound healing. Two main measurements, total angle of motion(TAM) and carroll, were significantly better than routine training and glove compression. Thus, early functional training combined with a hand flexion training band could improve the range of motion of the affected hand and promote the recovery of hand function. Nevertheless, some of the orthoses will immobilize the normal finger joints. Therefore, the application of them should wait for all affected fingers to be healed.

7. Somatosensory games and virtual technology rehabilitation

With the gradual maturity of virtual reality technology and the reduction of the cost of related hardware equipment, scholars and practitioners in the field of rehabilitation pay increasing attention to the development and application of VR rehabilitation. According to the degree of combination of virtual and realistic elements, the current virtual technology can be roughly divided into virtual reality (VR), augmented virtuality (AV), mixed reality (MR) and augmented reality (AR) [28]. At present, virtual reality is the most commonly used virtual technology in the field of rehabilitation. Motion-sensing game is based on the interaction between the video game and the realistic environment. Music, dance, various sports and simulated battlefield could be used as immersive game content. For achieving interaction, the game utilizes body sensors to track and collect human movements and reactions [29].

Pham[30] et al. developed Jintronix motion-sensing game software system on the Xbox360 Kinect platform according to the rehabilitation needs of burn patients. This game could customize personalized motion-sensing game content according to several factors such as age, burn area, burn site, interest and other needs of patients. After this game therapy, the range of motion of the joint was significantly improved. The inevitable pain, which often leads to resistance, fear, anxiety and depression, during joint stretching could be reduced when patients focus on playing games. Better training outcomes could then occur, especially among children. Lozano[31] et al. built a gaming therapy with Xbox Kinect among children with body surface burns (over 50%). The result illustrates that age and active range of motion were closely related to the score of the Child activity Scale, which involved personal care, dress, movement, stair climbing, playing, handling and standing skills.

Finger grasping is an essential movement for patients with joint spasticity to complete daily activities. For achieving this function recovery, precise interphalangeal joint functional training is required[31]. Leap Motion's accurate hand tracking technology has played a role in hand burns rehabilitation. Wu [32] et al. used Leap Motion somatosensory system to perform somatosensory games for 20 minutes for patients with hand burns after traditional rehabilitation treatment, including grasping, retrieving, shooting, holding and other actions related to hand abduction and adulation. Compared to the control group with only conventional therapy, the increased range of finger joint motion of patients (four months post-intervention) was statistically significant ($P<0.05$).

In addition to the above-mentioned, hydrotherapy, wax therapy, massage, electronic biofeedback, laser irradiation, and ultrasonic therapy have also been applied to a certain extent [22]. As Pessina[33] points out, the rehabilitation of burn patients requires multiple therapeutic collaborations, especially between burn therapists and nurses, throughout the whole loop of burn rehabilitation. Because of the particularity of hand burn scars, each method should be utilized depending on different circumstances and timing. Individual prescription is therefore required. Thanks to the advances of technologies, such as artificial intelligence, the developments of rehabilitation equipment and technology are accelerating the speed of burn rehabilitation and reducing the duration of therapy.

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