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Therapeutic Approach and Clinical Challenges in Managing Hand Scar Contractures

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Abstract

The primary principle in managing scar contractures is to address the loss of skin that results from releasing the contracted area, which is commonly restored using flaps or skin grafts. However, the unique attributes of scar contractures—including their location, configuration, and extent—differ substantially across patients, making preoperative planning complex. To achieve more predictable and effective outcomes, we formulated a three-dimensional classification framework for these lesions. This framework divides contractures into four groups: type 1 (shallow, linear scars), type 2-d (deep linear), type 2-s (planar but restricted to superficial layers), and type 3 (planar with deep involvement—thus, three-dimensional). When designing a surgical plan, three major parameters should be evaluated: (1) the size of the defect after release, (2) the amount of surrounding healthy tissue, and (3) the vascularity of the wound bed. Type 1 and type 2-d lesions are linear in shape; therefore, treatment usually involves direct excision and straight-line closure, using Z-plasty or modified versions to restore movement. In type 2-s lesions, following release, local flaps are preferred for small areas, pedicled perforator flaps for medium defects, and distant or free flaps for larger losses. Because type 2-s defects have well-perfused wound beds, full-thickness skin grafts remain an acceptable alternative regardless of the defect's scale. In type 3 contractures, release exposes deep structures—such as tendons, joints, or bone—with limited blood supply, making flap reconstruction preferable to grafting. Currently, there is no universally accepted grading system or therapeutic algorithm for such contractures. We suggest that objective dimensional classification and quantitative assessment can enhance both functional recovery and aesthetic results.

Keywords: Hand, Scar contracture, Dimensional classification, Skin defect, Limb reconstruction

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Background

Scar contractures restrict joint mobility due to skin tightening and must be differentiated from true joint contractures, where the joint capsule or structures are primarily involved. These typically develop in limbs, especially over joints aligned with longitudinal scars. The underlying mechanism is a deficiency of skin, which becomes apparent when the contracted tissue is released **(Figure 1)**.

Treatment is based on releasing the restrictive tissue and covering the resulting defect using flaps or grafts. Because the location, contour, and size of contractures differ widely, selecting the optimal surgical approach is often challenging. To improve both functionality and appearance, we propose a dimensional categorization system as the cornerstone for treatment planning. This article presents our surgical concept founded on this classification.

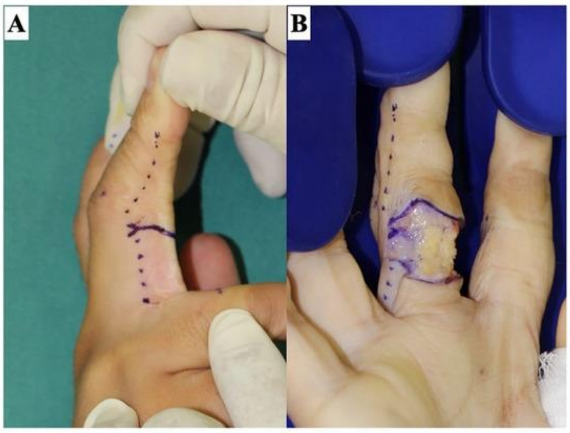

Figure 1. Release of a scar contracture line on a finger. When the contracted scar line is released, a skin gap becomes visible—the greater the contracture, the larger the resulting defect. The incision extends slightly beyond the midlateral line (dotted), and a Y-shaped cut creates a zigzag margin that minimizes the risk of recurrence. All scar tissue within the wound is carefully dissected and excised until healthy subcutaneous fat is reached. (A) Incision design; (B) Post-release appearance

Assessment of Scar Contractures

A precise understanding of the cause of contracture is crucial for selecting an appropriate surgical approach. Etiologies fall into two broad groups: extra-articular (including scar tightening, tendon adherence, and muscular shortening) and intra-articular (involving contracture of periarticular tissues, capsular shrinkage, or articular destruction) **(Figure 2)**.

Occasionally, both forms coexist—for instance, severe trauma may affect layers from skin to joint, or joint stiffness may develop as a consequence of extensive scarring. It is critical to avoid misdiagnosing a deep joint involvement as merely cutaneous, since an operation planned as simple scar release with grafting may unexpectedly require flap reconstruction once deeper adhesion is encountered intraoperatively. Therefore, comprehensive preoperative evaluation is essential.

To distinguish skin-related from joint-origin contractures, two diagnostic steps are recommended.

1. For proximal interphalangeal (PIP) joint limitation, if the problem is due to scar tissue, passive extension of the PIP causes blanching of the scar **(Figure 3)**. During surgery, release should target the most restrictive zone.

2. By flexing the metacarpophalangeal (MCP) joint and loosening the palmar skin, the surgeon can attempt passive PIP extension. In scar contractures, this allows smooth extension, while in true joint contractures, extension remains limited even when the skin is relaxed **(Figure 4)**.

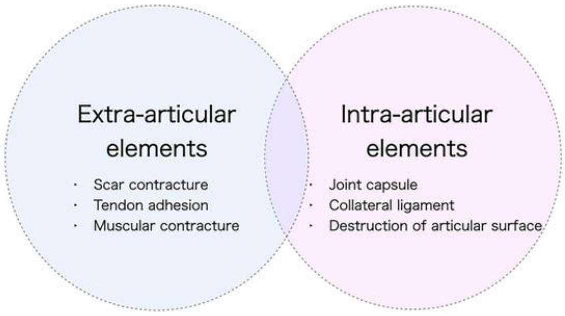

Figure 2. Origin of contracture

Contractures are generally divided into two categories based on their cause: those resulting from factors external to the joint (extra-articular) and those that arise from within the joint itself (intra-articular). Scar contractures belong to the extra-articular group, as they are caused by the skin rather than joint structures.

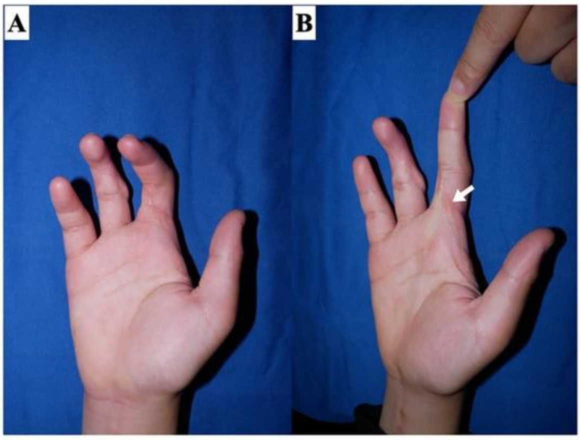

Figure 3. Clinical appearance of a scar contracture

In cases of scar contracture, when the affected joint is passively extended—thereby stretching the skin—the scar turns pale (indicated by the white arrow).
(A) Relaxed hand position.
(B) Passive extension of a finger affected by scar contracture.

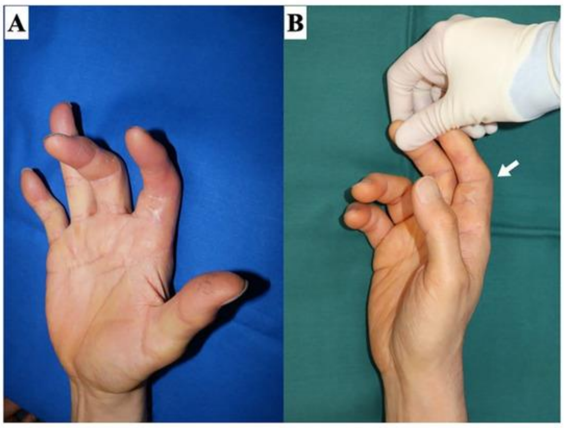

Figure 4. Clinical presentation of joint contracture

For PIP joint contractures, even when the surrounding skin is relaxed, the joint cannot be straightened either passively or actively.
(A) Relaxed posture.
(B) PIP joint showing lack of extension (white arrow).

Surgical Indication and Timing

Hand scar contractures can cause diverse symptoms that limit function, and the extent of disability perceived varies greatly between individuals. This perception depends on personal needs, occupational activities, and even cosmetic concerns. Manifestations range from a mild sense of tightness with minimal restriction of movement to severe deformities leading to tendon adhesion or joint stiffness.
Undoubtedly, patients with significant functional or aesthetic impairment are candidates for surgical correction. However, recent patient satisfaction research highlights that improving appearance alone can greatly enhance psychological and functional satisfaction [1–3]. Therefore, aesthetic-based surgery may be justified even in mild cases where functional loss is minimal. More evidence is needed to fully support this approach.
Once acute burns or traumatic wounds have healed and epithelialized, early initiation of joint mobilization—preferably under supervision of a hand therapist—is crucial to avoid joint stiffness. The use of nighttime splints helps to prevent contracture formation. Additionally, compression garments and steroid tapes applied to maturing scars can minimize hypertrophy [4].
Ideally, surgery should be postponed until the scar tissue has matured, a process that usually requires 6 to 12 months [5–7]. Nevertheless, when severe functional limitation or a risk of joint involvement exists, early surgical intervention is warranted.
Children are especially susceptible to developing contractures. For example, flexion deformities of the PIP joint may impair extensor tendon mechanics if the finger remains bent for a prolonged time. Thus, once the wound heals and contracture forms, prompt surgery is recommended. Because children continue to grow, recurrence of contracture may occur; therefore, the timing of repeat procedures should be carefully planned based on the child’s age and growth phase.

Treatment Strategy for Scar Contractures of the Hand

The core issue in scar contracture is insufficient skin coverage. After releasing the contracted area, this deficiency becomes evident as a skin defect, which must be reconstructed both functionally and aesthetically to prevent recurrence.

For hand contractures, flap reconstruction—using adjacent healthy tissue, local flaps, or pedicled perforator flaps—is generally favored over skin grafting. The main limitation of grafts is their tendency to undergo secondary contraction, which may result in recurrent tightening over time. This risk is particularly high for thin grafts [8,9]; hence, full-thickness grafts are generally preferred.
When donor skin is harvested from non-hand sites (such as the groin or lower abdomen), the resulting color and texture mismatch may cause a patch-like appearance. In contrast, flap transfers allow gradual longitudinal expansion through natural stretching [10], thereby minimizing the likelihood of new contractures.
Selecting local or pedicled perforator flaps enables reconstruction with similar tissues, producing excellent functional and cosmetic results. Moreover, using flaps rather than grafts eliminates the need for immobilization during tie-over fixation, allowing early postoperative rehabilitation. Even if future procedures such as tenolysis or joint release are necessary, outcomes are superior when the skin envelope has been reconstructed with a flap.
However, flap-based reconstruction is suitable only for small to medium defects surrounded by healthy skin **(Figure 5)**. When choosing the reconstruction method after scar release, three main considerations should be evaluated:
(A) Defect size,
(B) The presence or absence of intact skin around the area, and
(C) The vascular status of the wound bed.
Defects are classified as small, medium, or large—but rather than the absolute dimensions (in cm), their anatomical site is the critical factor. For example, a 2 cm defect on the palm is considered minor, while the same 2 cm gap on a digit represents a large defect.

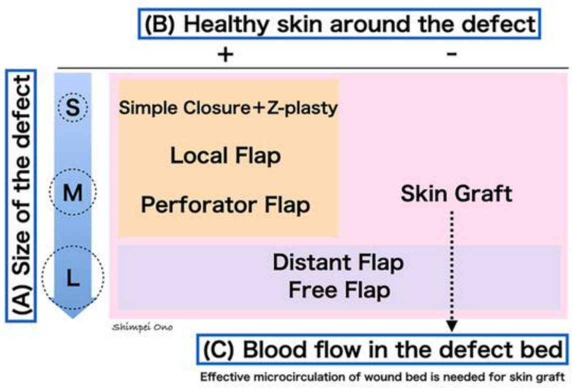

Figure 5. Framework for managing hand scar contractures
When planning reconstruction after scar release, consider:
(A) Defect size,
(B) Availability of healthy donor skin, and
(C) Condition of the vascular bed.

Abbreviations: S, small-sized; M, medium-sized; L, large-sized.

Small-Size defects

When viable skin is present around a small defect, the preferred treatment options include direct closure, z-plasty, or conventional local flap techniques. After performing a straight-line suture, one or more minor z-plasties may be added to improve tissue mobility. If contracture release remains insufficient with z-plasties alone, switching to a local flap is advisable. A particularly effective approach is rotating a transposition flap by approximately 90° to fill the gap created after dividing the contracture band. In both cases, the contracted line is separated by interposing healthy skin between adjacent tissue segments.

Medium-Size defects

For moderate-sized defects surrounded by unaffected skin, a pedicled perforator flap or regional flap is recommended. These flaps provide a less invasive solution, preserving the main arterial supply. The method involves rotating a skin island—similar to a propeller—around a nearby perforating vessel to cover the exposed area [11]. Because the perforator is retained, stable perfusion is maintained, and the flap's rotation allows for an extended coverage zone. Pedicled perforator propeller flaps are particularly valuable for limb reconstruction, where donor sites are limited. Such flaps can be rotated up to 180 degrees and are typically harvested along the longitudinal axis of the limb [11].

Large-Size defects

In extensive defects where local skin transfer is not feasible, free or distant flaps become the treatment of choice.

Alternatively, if healthy skin is absent around the affected area—as in post-burn contractures involving widespread body regions—skin grafting should be prioritized, regardless of the defect's scale **(Figure 5)**. Graft survival depends on adequate vascularity of the wound bed, thus grafting is unsuitable when key underlying structures with poor circulation (e.g., tendons, bones, joints) are exposed. Most scar contractures, however, retain acceptable subcutaneous blood flow. When deep scarring exists (from severe trauma involving soft tissues) or the vascular condition is compromised (e.g., post-radiation cases), free or distant flaps are preferable for reliable coverage.

Treatment Selection Based on Dimensional Classification

Dimensional categorization of scar contractures

For systematic planning, scar contractures can be topographically classified into one-, two-, or three-dimensional types **(Figure 6)**. Superficial lesions fall under two subtypes: superficial linear (Type 1) and planar superficial (Type 2-s). Deeper lesions are classified as deep linear (Type 2-d) or deep planar/three-dimensional (Type 3).

Type 1 typically results from small cuts, Type 2-s from partial-thickness burns, Type 2-d from surgical scars near joints, and Type 3 from high-impact trauma such as crushing injuries. Type 3 lesions may coexist with true joint contractures. Accurate preoperative palpation helps identify depth involvement. Limited range of motion often indicates adhesion to deeper layers. The extent of scarring can be roughly estimated by passive stretching, flexion, or pinching maneuvers **(Figure 3)**. Since scar tissue depth is rarely uniform, with mixed shallow and deep zones, this assessment serves as a practical guideline for defining the operative plan.

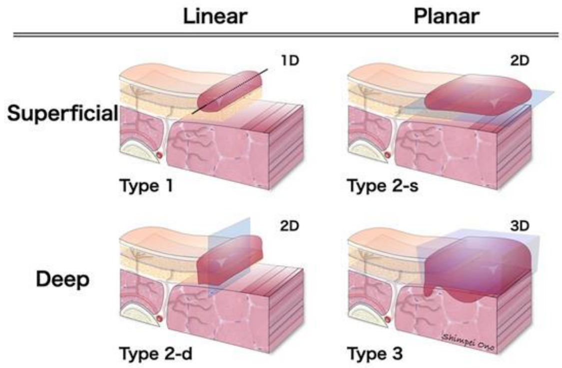

Figure 6. Dimensional categorization of scar contractures. Contractures are grouped by depth and geometry as follows: Type 1 (superficial linear), Type 2-d (deep linear), Type 2-s (planar, superficial), and Type 3 (planar or three-dimensional, deep-layer)

Scar contracture release techniques

When sufficient healthy skin surrounds the contracted area, extensive excision of scar tissue should be undertaken. If viable skin is lacking, it is safer to avoid over-resection. The contracture line, usually oriented longitudinally, must be divided where tightness is greatest **(Figure 1)**.

For digital palmar deformities, recurrence prevention requires the dorsal margin of the graft or flap to reach or surpass the midlateral line **(Figure 7)**. Longitudinal sutures that intersect palm creases at right angles tend to form hypertrophic scars and recurrent contractures. To counter this, incisions should follow a zigzag path or incorporate small z-plasties at crease intersections **(Figure 8)**.

Another essential aspect is complete removal of fibrotic bands contributing to the contracture, both superficially and deeply, until healthy adipose tissue is visible. During this step, dissection should be carried out under magnification to protect the neurovascular bundles and avoid unnecessary release of the tendon sheath.

Incomplete excision of the causative fibrotic tissue may worsen the condition postoperatively, as residual tension combined with surgical trauma can promote re-contracture formation.

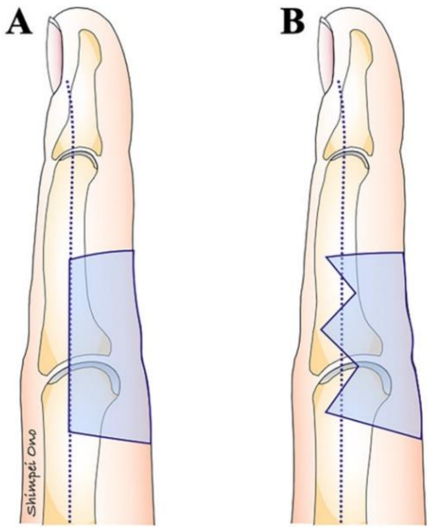

Figure 7. Configuration of a defect after releasing a scar contracture on the palmar aspect of a finger. Aligning or extending the defect edge beyond the midlateral line toward the dorsal side reduces the likelihood of secondary contraction in the grafted skin. (A) Dorsal edge of the donor coincides with the digit's midlateral line. (B) Dorsal edge extends past the midlateral line, with a zigzag pattern

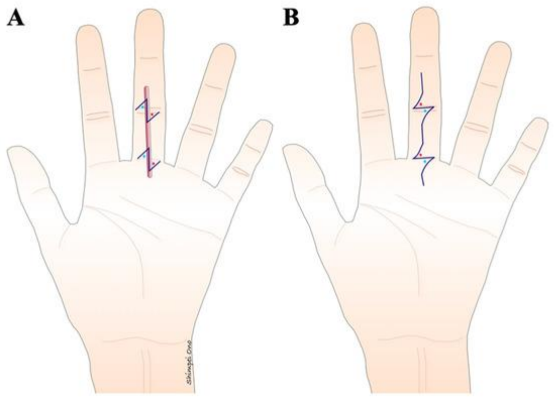

Figure 8. Z-plasty design for a linear scar crossing digital creases perpendicularly. (A) Scars perpendicular to digital creases tend to produce contractures, necessitating z-plasty placement along the crease. (B) Lateral limbs of the z-plasty are aligned with the crease following flap transposition

Treatment guidelines for each scar contracture type

For Type 1 (superficial linear scar contracture) **(Figure 9)** and Type 2-d (deep linear scar contracture) **(Figure 10)**, excision of the scar is followed by straightforward suturing, with z-plasties added along skin creases due to sufficient surrounding healthy tissue. Z-plasties aim to integrate normal skin into the contracture line from both sides [12]. Placement should be in non-scarred tissue. Typically, the Z's angle is 60°, with the achievable lengthening approximately 1.7 times the length of one side of the Z. Severe contractures may require multiple z-plasties. Simply increasing the side length does not proportionally increase elongation and may worsen scar visibility or skin distortion. Optimal side lengths are 5–8 mm for digits and 10–15 mm for the hand. For significant contractures, techniques with greater lengthening—multi-z-plasty, 4-flap or 5-flap z-plasty, or square flap methods—are recommended.

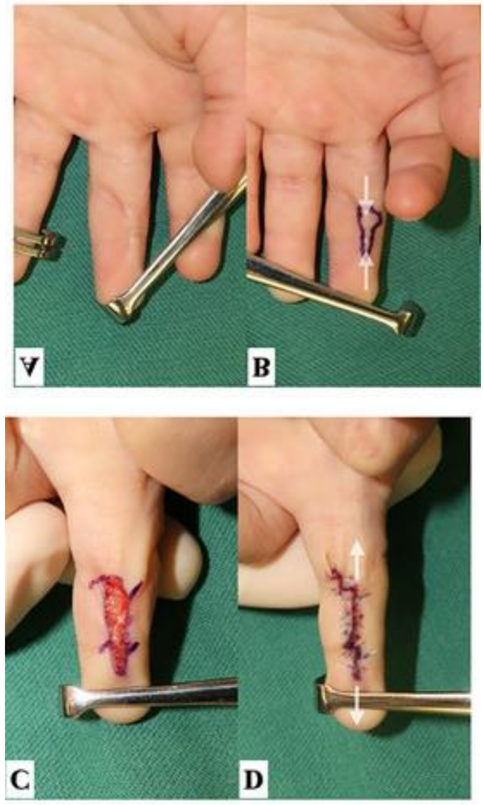

Figure 9. Type 1: superficial linear scar contracture. Male, 3 years old, post-contact burn. (A) Long finger scar contracture. (B) Linear scar along the palm from DIP to PIP joint (white arrow). (C) Z-plasty design over skin crease after release. (D) Vertical orientation of postoperative scar

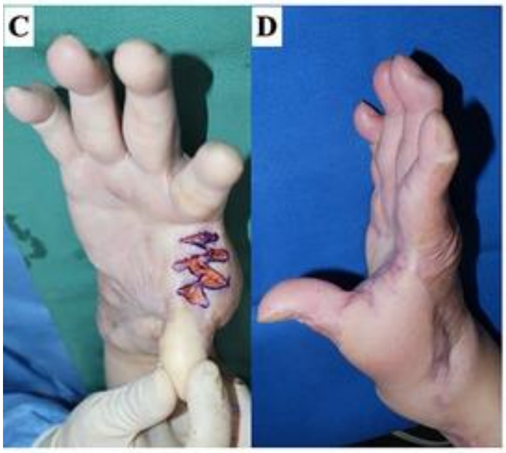

Figure 10. Type 2-d: deep linear scar contracture. Female, 49 years old, post-burn reconstruction with radial artery perforator flap. Contracture occurred along flap margin near first web space. (A) 5-flap z-plasty design. (B) Proper flap design enables natural repositioning upon incision and release. (C) Immediately post-suturing. (D) Six months postoperatively, thumb abduction improved

For Type 2-s (planar, superficial scar contracture) **(Figure 11)**, the treatment approach depends on defect size. Small defects: direct suturing with z-plasty or a local flap. Slightly wider band-shaped contractures: divide the line and rotate a transposition flap 90° into the defect. Medium defects: pedicled perforator flap is preferred. For limbs, a propeller-like rotation from a proximal area of excess skin to the distal defect is effective. Alternatively, the joint area can be reconstructed with a local or pedicled flap, and other areas covered with a skin graft. Blood supply in the defect bed is generally adequate, making full-thickness skin grafting viable.

Figure 11. Type 2-s: planar, superficial scar contracture. Male, 47 years old, right upper arm post-flame burn. (A) Transposition flap design. (B) Intraoperative view showing inclusion of perforator in flap pedicle. (C) Immediately after suturing. (D) Normal skin between scar lines gradually widens over time.

Type 3 (planar scar contracture reaching the deep layer; three-dimensional) represents the most severe form **(Figure 12)**. Releasing such contractures exposes critical structures with poor perfusion (tendons, joints, bones), making skin grafting suboptimal. Treatment recommendations: small defects, primary suture or local flap; medium defects, pedicled perforator flap; large defects, free or distant flap.

Figure 12. Type 3: planar scar contractures extending into deep layers (three-dimensional). A 29-year-old male with a flame burn history presents with wrist contracture. (A) The scar extends from the wrist toward the thumb. (B) Design of a radial artery perforator flap. (C) Flap elevation during surgery. (D) Flap transposed to cover the defect after releasing the scar and underlying transverse carpal ligament. (E,F) Twelve months postoperatively, wrist extension is fully restored

Although the focus above was on flap reconstruction, as noted in **Figure 5**, skin grafting can be performed regardless of defect size if the underlying blood supply is adequate. Moreover, a hybrid approach—covering exposed joints or critical structures with a flap and other areas with skin grafts—is also effective. For scar contractures, full-thickness skin grafts are preferred to reduce secondary contraction. When grafting palmar hand or finger defects, donor sites with similar tissue, such as the palmar hand or plantar foot, are ideal, though the amount available is limited. Suitable donors include thick split-thickness skin from the thenar, hypothenar, or plantar areas, harvested with a skin knife [13]. Full-thickness grafts can also be taken in a spindle shape so that sutures align with palmar creases, the hand midlateral line [14], or the submalleolar crease. For extensive contractures, groin skin is often chosen for its size, despite differences in texture and color, with scars concealed under clothing.

Once defect size is determined, skin is harvested, and the pinch test confirms the width that can be sutured. Ideally, one continuous graft should cover the defect, as multiple grafts create scarring at junctions. Uniform tie-over pressure is crucial, with sutures spaced about 1 cm and anchored to prevent graft movement, hematoma, or seroma formation.

For circumferential or extensive burns affecting joints and extremities, the defect is large, and healthy donor tissue may be scarce, especially in children. Recurrence risk inversely correlates with dermis quantity, and wound bed condition impacts scar contracture outcomes [15,16]. Artificial dermis can be applied to prepare the wound bed before grafting, improving range of motion and reducing recurrence rates [16,17,18].

Surgical planning should assume one severity grade higher than diagnosed. For instance, misjudging a Type 1 as mild, then encountering a Type 2 with a larger defect, may lead to complications.

Postoperative management

Following scar contracture release, the target joint requires immobilization. External fixation, such as a cast or aluminum splint, is common. For children, temporary Kirschner wire insertion is used to maintain position, but removal should occur within 1–2 weeks to prevent joint stiffness. Immediately post-surgery, the limb should be cooled and elevated, with elevation maintained for 1–2 weeks. Immobilization supports wound healing, while gentle active motion of movable joints should start early to aid lymphatic and venous return and prevent edema. Once the wound has healed, usually 1–2 weeks postoperatively, joint rehabilitation begins under a hand therapist's guidance. Active and passive mobilization should occur frequently (approximately 5 min per hour) without causing pain. Limbs remain splinted outside rehabilitation sessions for 2–3 weeks, then only at night for at least 3 months.

When any scar induration appears, nighttime steroid tape should be applied immediately, as movement may dislodge daytime application. For severe digital edema, self-adherent wrap bandages can be used. Postoperative therapy is as vital as surgery in managing scar contractures.

Conclusions

This review outlines treatment strategies for hand scar contractures, which frequently occur in long-axial scars over joints. Surgical planning must consider:
(A) defect size,
(B) availability of donor skin around the defect, and
(C) vascular microcirculation in the defect bed.
Based on the dimensional classification of scar contractures, an appropriate treatment—ranging from sutures, local flaps, pedicled flaps, free flaps, to skin grafts—can be selected for optimal functional and aesthetic outcomes.

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