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Research Article

Exploration of Scar Surface Deficit as a Cause of Postburn Scar Contractures

Viktor M. Grishkevich* and Max Grishkevich

Department of Reconstructive and Plastic Surgery, A.V. Vishnevsky Institute of Surgery of the Russian Academy of Medical Sciences, Russia

***Corresponding author**

Viktor M. Grishkevich, Department of Reconstructive and Plastic Surgery, A.V. Vishnevsky Institute of Surgery of the Russian Academy of Medical Sciences. Moscow, Russia, Tel: 503-888-1099; Email: grishkevichmail@gmail.com

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Abstract

Background: Anatomy and causes of postburn scar contractures are insufficiently researched and commonly accepted anatomic principles for choice of local-flap technique for reconstruction is not developed. All existing techniques for the treatment of postburn scar contractures with local tissue are based on triangular flaps. Z-plasty and Y-V procedures have many disadvantages and the results of treatment of contractures are thus far from perfect.

Methods: More than three thousands patients with postburn scar contractures in different locations and of different severity were operated on by the authors. Unsatisfactory functional results after the use classical local-flap techniques (Z- and Y-V plasty) prompted more in depth research of the anatomy and causes of contractures and classification of anatomic features. We anticipate our data to help develop a new approach to local flap design and reconstructive techniques.

Results: The cause of edge and medial contractures is a scar surface deficit in length in the joint flexion lateral (FL) and flexion medial (FM) surface and scar fold sheets, lateral sheets of commissure, and neck. The deficit, as a rule, has a trapezoid form. Scar surface deficit of the total contracture does not have a specific form. The fold is a new anatomic structure and scar and skin surface surplus are used for the treatment of contractures Adequate treatment of edge and medial scar contracture is concluded in scar surface deficit compensation with similar local trapezoid flap flaps from fold sheets and neighboring skin, using trapeze-flap plasty, yielding excellent functional and good cosmetic outcomes.

Conclusion: The actual cause of contracture is a trapezoid scar surface deficit of scars covering the joint flexion lateral or medial surfaces and scar fold's sheets. Both sheets of the fold are surface surplus allowing edge and medial (80% of the total number) contracture elimination with trapeze-flap plasty. Triangular flaps do not match scar surface deficit; therefore, the further use of Z- and Y-V plasty and their modifications are not justified.

INTRODUCTION

In spite of significant achievement in burn treatment, the incidence of scar contractures is high [1]. Among three burn consequences - scar deformity, contracture and tissue defect – contractures most often lead to disability. Therefore, the efficacy of scar contractures treatment has paramount meaning in the surgical rehabilitation of burned patients. The complete contracture removal significantly improves the appearance of the contracted region. Over many years, the scar contracture treatment is in line with classic teachings, especially concerning the local-flap techniques. Triangular-flap techniques – Z- and Y-V plasty modifications and combinations – continue to serve as the basis for scar contractures treatment [2,3]. Our vast experience in treatment of postburn scar contractures showed that all techniques based on triangular flaps cannot fully eliminate scar contracture and repeat surgeries were often needed. Our research and literature review showed that lack of progress in rehabilitation of burned patients is caused by insufficient exploration of: (a) contractures' anatomy, (b) absence of clear information on scar surface deficit as contracture cause and (c) anatomical classification of scar contractures. Therefore, results of rehabilitation of the burned patients with contractures are far from perfect [4]. Results of our researches allowed determining anatomic features of all scar contractures and developing anatomically based classification. Contractures cause was determined and a new flap and new surgical technique developed according to scar surface deficit which solved problem of post burn scar contractures treatment and elevated rehabilitation of burned patients to a new level. All new data are presented in this paper.

Highlights:

- Current treatment options of postburn scar contractures are far from perfect.
- It is caused by insufficient researches of anatomy contractures, its cause or scar surfaces deficit and the usage anatomically non substantiated local triangular flaps and techniques.
- New data concerning contractures anatomy, scar surface deficit and new methods of reconstruction elevated rehabilitation of burned patients to as new level.

MATERIAL AND METHODS

Since 1979, the author has surgically treated over three thousand patients with postburn scar contractures of different joints and body areas in a specialized Department of Reconstructive and Plastic surgery, which contained 55 beds. Different surgical methods were tested and results were compared. The known disadvantages and complications of classic methods (Z- and Y-V plasty) were noted. Analysis made clear that the cause of unsatisfactory out comes is insufficient research of contracture cause. Therefore, the anatomy of scar surface deficit as contracture cause was studied during the operations, depending on the contractures' location and severity and scars spread. The contracture cause (scar surface deficit) was explored for understanding what form of local flaps and techniques are most suitable for contracture elimination. New flaps (trapezoid) and new techniques (trapeze-flap plasty) were used in more than 2000 patients for the treatment of scar contractures of different location and severity. Study results were compared to results of the classic techniques. All contractures were classified into three types: edge, medial, and total [5].

RESULTS

Anatomy of postburn scar contracture

Functional zones of joints, neck and body surfaces undergoing contractures (Figures 1-3)**:** Three types (form) of postburn scar contracture exist: edge, medial, and total. In the plane of surgical treatment, the joint surface is divided in to flexion (F) and extension (E); the boundary between them passes along the joint rotation axis level-"+" (Figure 1). The flexion surface of large joints (axilla, elbow, knee, ankle and wrist) is divided in two zones: flexion lateral (FL) and flexion medial (FM). The lateral surface of the big joints is spread from the edge of the joint fossa to the joint rotation axis level; the flexion medial surface includes the space of the joint's fossa and ankle anterior surface; the scars, forming the commissural contractures, spread from the fold crest on the dorsal and palmar hand or cheek. All flexion surfaces of the small (inter phalangeal) joints, anterior and lateral neck, lateral trunk and perineum are considered as one flexion medial surface.

Edge scar contracture anatomy (Figures 1,4- 11)**:** Burns and scars, located on the lateral joint's flexion and lateral commissural surface (FL), growing distally, involve healthy skin of joint flexion medial (FM) surface and inner surface of commissure, and form the fold. The fold is located along the edge of joint fossa, commissural fossa and ankle anterior surface; the crest of the fold (Cr) is the scar's edge. In the fold, only the lateral sheet is scar and continuation of scars covering the flexion lateral surface. Both sheets area new anatomic structure and surface surplus of scar FL surface; and the medial sheet of the fold of neighboring joint's fossa (FM surface), commissural fossa, first web space, and ankle anterior surfaces is the healthy skin and are donor sites, allowing contracture elimination with local tissue flaps. Neck edge contractures are caused by scars covering posterior or unilateral neck surfaces; the fold passes along the middle cervical, lateral or anterior surface. Thus, the edge contractures are characterized by four signs: (a) contracted scars causing contracture covering big joint flexion lateral surface, hand dorsal or palmar surface, neck posterior surface and form the fold; (b) the fold is located along edge joint fossa's and commissural edge and lateral neck; (c) in the fold the lateral sheet is scar, and medial sheet is healthy skin; (d) the crest of the fold is the edge of scars.

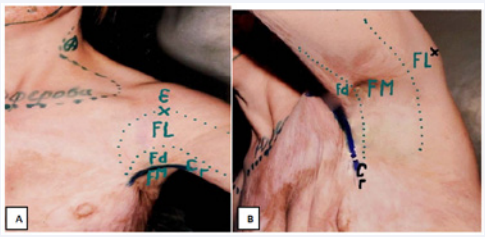

Figure 1 Anatomic features of shoulder edge adduction contractures pertaining to all edge contractures. (A and B) Functional zones
Abbreviations: E: Extension Surface; F: Flexion Surface: FL: Flexion Lateral Surface; Fd: Fold; FM: Flexion Medial Surface; Symbol "+" Joint Rotation Axis; Cr: Crest of the Fold and Edge of Scars. Anatomic and Clinical Signs: Scars on FL Surface; Fold Located along Edge Join Fossa (FM surface) and Commissural Edges; Lateral Fold's Sheets are Scars, Medial Sheet is Healthy Skin; Crest (Cr) of the Fold is the Edge of Scars.

Figure 2 Medial contracture anatomy. (A and B) Joint functional zones as in case of edge contracture. Anatomy and clinical signs: scars are located on joint flexion medial (FM) surface or joint fossa; fold passes along the medial line of FM surface; both sheets of the fold are scars.

Anatomy of medial scar contracture (Figures 2,12-22)**:** Scars covering the flexion medial (FM) surface (fossa of large joints), ankle anterior surface, finger flexion surface, commissural fossa, first web space, neck anterior and lateral surface, nose, lateral trunk and perineum, grow distally, forming the fold which is scar surface surplus. The fold passes along the medial line of the joint's flexion surface, commissural and first web space fossa, perineum, lateral trunk, dorsum nose, neck anterior and lateral surfaces. Both sheets of the fold are scars, have surface deficit in length and surplus in width, the surface of which is enough for contracture elimination with local flaps. Lateral flexion surface of the large joint is healthy skin or covered with scars that do not participate in contracture formation. Thus the scars, located on the flexion medial surface of large joints, commissural fossa, perineum, nose, neck anterior and lateral surfaces, and lateral trunk and forming the fold in which both fold's sheets are scars, create the medial contracture type. The medial scar contractures

Figure 3 Total contracture anatomy. Scars cover all joint flexion surface or circularly without a fold.

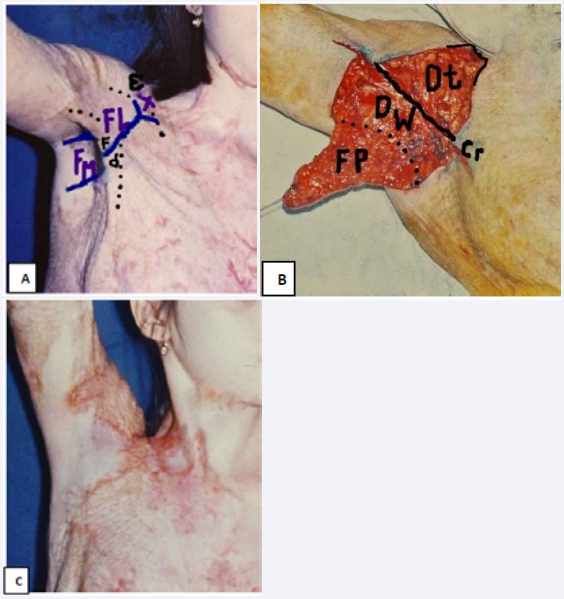

Figure 4 Edge shoulder anterior adduction contracture caused by trapeze-shaped scar surface deficit. (A) Before surgery, functional zones(FL-flexion lateral) FM- flexion medial surface, fold (Fd) along fossa's anterior edge; "+"- joint rotation axis; E- joint extension surface; trapezoid flap in axilla; (B) contracted scars dissected from the fold's crest to the joint rotation axis with a Y-shaped incision; after shoulder abduction, the wound (Dt- scar surface deficit) accepted a trapezoid form; mobilized axillary adipose-cutaneous trapezoid flap (FP); WD-donor wound. (C) Contracture fully released (one year after surgery).

are characterized by three signs: (a) scars that cover a big joint's flexion medial surface (FM), all flexion surface of small joints; anterior and lateral neck, lateral trunk and perineum; (b) scars from the fold of the crest which passes along the middle line of FM surface, small joint, anterior and lateral neck, lateral trunk and perineum, (c) both sheets of the fold are scars.

Total contracture anatomy (Figures 3,23)**:** Deep and vast burns and scars, injuring the joint's flexion lateral and medial surfaces without fold form tightly surround the joint. Severe scar surface deficit appears, limiting the possibilities of any local-flap technique; large wound/scar surface deficit is covered with skin grafts, regional pedicle and free flaps.

Technique for full contracture release and scar surface deficit exploration

The reconstructions with classic local techniques for scar contracture treatment (Z- and Y-V plasty and their modifications and combinations) are performed with linear incisions of contracted scars under different angles to the fold's crest. As a rule, a triangular wound is created, which is covered with a triangular pointed flap (transposition and advancement).

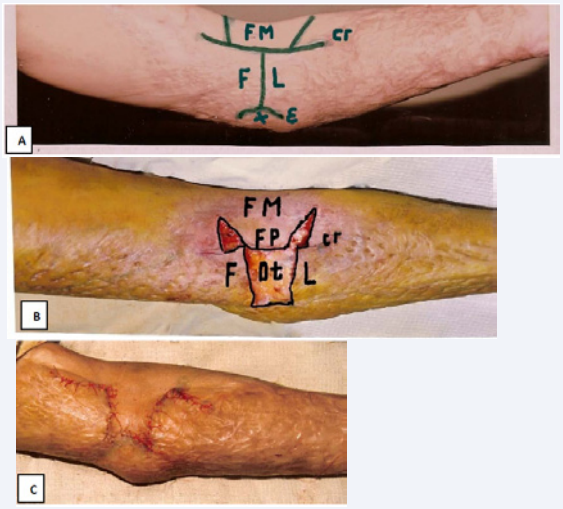

Figure 5 Edge elbow flexion contracture caused by scars covered joint flexion lateral (FL) surface, having trapeze-shaped surface deficit.
(A) Before surgery, functional zones(FL-flexion lateral surface; FM- flexion medial surface (joint fossa), E- joint extension surface; "+"- joint rotation axis; planning of operation - trapeze-flap plasty: line along fold crest, Y-line-scars dissection from the fold crest to the joint rotation axis; elbow trapezoid flap; (B) scars dissected with Y-incision, a trapezoid wound appeared (Dt- scar surface deficit), trapezoid elbow fossa flap (FP) mobilized; (C) contracture fully released; adipose-cutaneous trapezoid flap scar surface deficit compensated and contracture eliminated.

Figure 6 Edge first web space adduction contracture caused by trapeze-shaped scar surface deficit of scars formed fold along dorsal edge of fossa. (A) Pre-operative view; contracture caused by scars that formed the lateral sheet of the fold; (B) contracted scar sheet of the fold dissected with a Y- incision, trapezoid wound –Dt- (scar surface deficit) appeared (upper strip); trapezoid flap –FP- elevated from fossa. (C) Scar surface deficit compensated and contracture eliminated (three years after trapeze-flap plasty).

Figure 7 Dorsal interdigital edge adduction contractures (syndactyly) caused by the fold and scar surface trapezoid deficit in lateral scar sheet; (A) Before operation, severe syndactyly; (B) fingers separated; scar sheet of the fold dissected with a Y-incision, a trapezoid wound appeared, Dt (scar surface deficit), elevation of a matching flap in interdigital fossa (FP); (C) contracture completely eliminated.

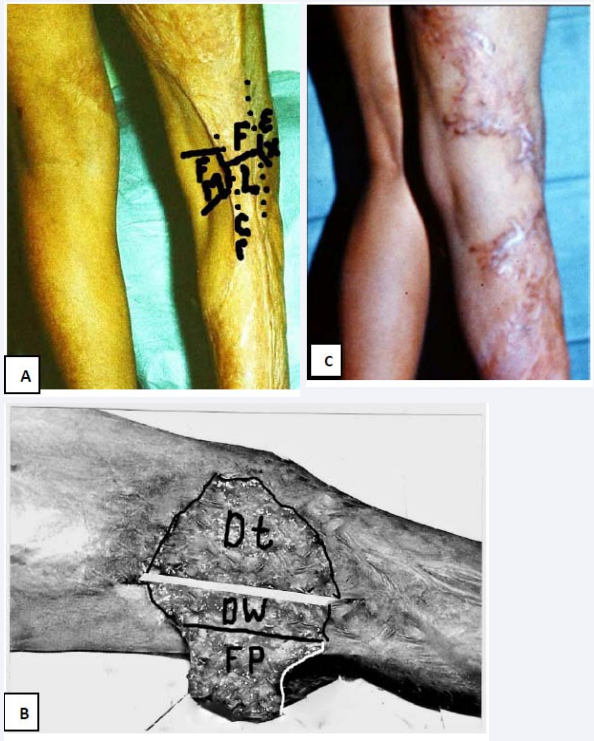

Figure 8 Knee edge flexion contracture, caused by scar surface trapezoid deficit, eliminated with knee fossa trapezoid adipose-cutaneous flap. (A) Anatomy of contracture: scars covered joint flexion lateral surface (FL) from the fossa's edge to the joint rotation axis and formed a fold along the fossa's edge; knee fossa or flexion medial surface- FM- is healthy skin; Cr- crest of the fold; "+"- joint rotation axis; E- joint extension surface; planning of operation: Y-line for contracted scar dissection and separation scars from the crest of the fold to the joint rotation axis ("+"); trapezoid flap in knee fossa; (B) scars Y-incised from fold crest to the joint rotation axis, deficit –Dt- appeared (wound and contracture cause), knee trapezoid flap- FP- mobilized; (C) excellent outcome: trapezoid flap deficit compensated and contracture eliminated, flap's surface increased.

Figure 9 Ankle edge contracture caused by scar surface deficit, located on joint flexion latera (FL) surface; left picture-anterior surface - FM- is healthy skin; Cr- crest of the fold; typical planning one-flap trapeze-flap plasty: Y-line for scar dissection and separation from neighboring extension zone; trapezoid flap on ankle anterior surface; middle picture – scar dissected, trapezoid wound and scar surface trapezoid deficit – Dt- appeared (contracture cause); trapezoid flap- FP- mobilized; DW- donor wound; right picture- contracture eliminated and scar surface deficit compensated with a trapezoid flap.

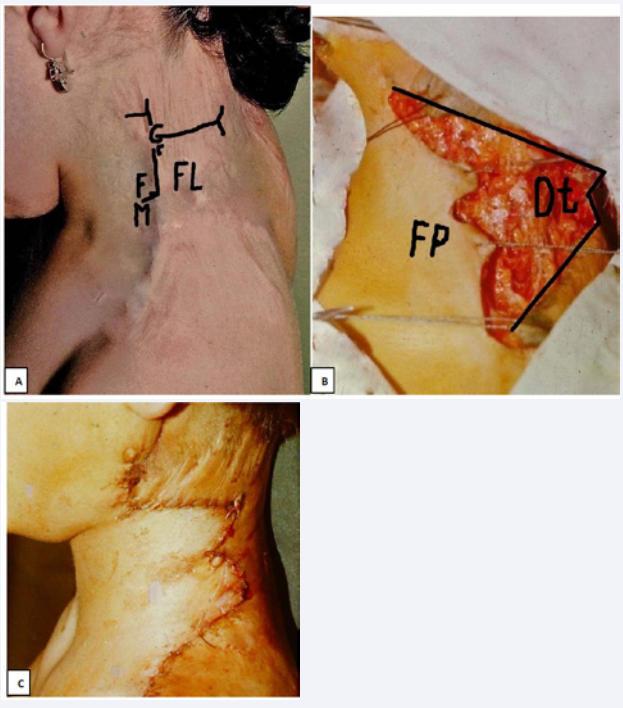

Figure 10 Lateral edge neck contracture caused by scar sheet's surface deficit in the trapezoid form.
(A) Before operation: typical contracture anatomy: scars on posterior surface (FL) of the neck, fold on lateral neck, Cr-crest of the fold; posterior fold's sheet is scar; medial (anterior) sheet is healthy skin; planning of one-flap trapeze-flap plasty; (B) after scar sheet dissection with a Y-shaped incision, big trapezoid wound appeared (trapezoid scar surface deficit –Dt, contracture cause). (C) mobilized flap (FP) from the fold's healthy sheet and neck anterior surface scar surface deficit compensated and contracture eliminated.

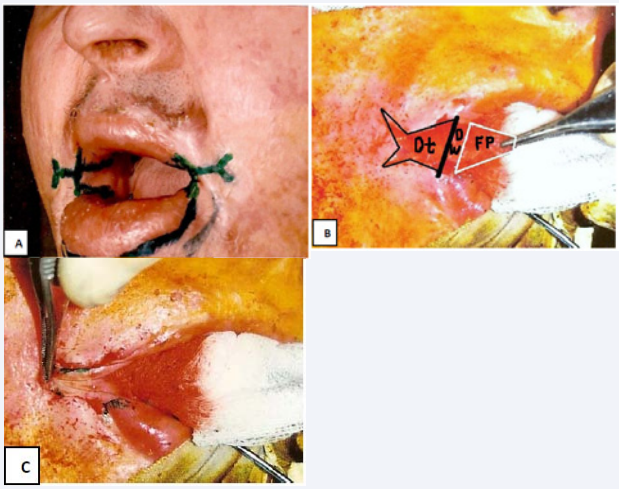

Figure 11 Microstomia caused by trapezoid surface deficit in lateral scar sheet of the fold. (A) Pre-operative view: scars on cheek caused a fold in commissural angle; planning of operation (trapezoid flap and a Y-incision of scars); (B) after dissection of the fold's scar sheet with a Y-shaped incision, trapezoid wound appeared, Dt- deficit (contracture cause); trapezoid flap – FP – mobilized from inner medial sheet; DW – donor wound. (C) Flap covered the wound, scar deficit compensated, and microstomia eliminated.

Figure 12 Medial axillary adduction contracture caused by a trapezoid scar surface deficit of axillary fossa (FM surface), having surface deficit in length of both scars' sheet of the fold and surface surplus in width. (A) Before surgery: scar fold along medial line of axilla (planning of operation- one pair of trapezoid flaps from all axilla); B – (left) flaps mobilized after fold's dissection along the fold and with two radial incisions and opposite flaps' mobilization, two trapezoid wounds appeared having a common base (white strip); FP- flap; Dt- scar surface deficit, DW-donor wound; (right) additional pair of scar trapezoid flaps mobilized for complete contracture release, counter transposed flap scar surface deficit compensated and contracture eliminated. (C) Follow-up: functional results are excellent, cosmetically, acceptable.

After separation of the fold's sheets with incisions along the fold crest and perpendicular dissection of contracted scars with a linear incision, the wound accepts the triangular pointed form in all cases of edge and medial scar contractures. The healthy tissues, located on the joint's extension surface (in case of edge contracture) or neighboring skin of flexion lateral surface (medial big joint contractures), are tightly connected to the scar; therefore, the edges of triangular wounds do not diverge and the contracture is not fully released. For complete contracture release, the linear incision should be extended on to neighboring tissue, where the contracture is absent, and make the triangular wound larger, necessitating larger triangular flap. Therefore, for complete contracture release, the wound edges of dissected scars should easy diverge. For this contracted scars are separated from neighboring tissue from both sides of edge. First incision passes along fold's crest and separates scar sheet from healthy skin of FM surface. Second Y-incision dissects contracted scars and separates from joint extension surface (E) along the joint rotation

Figure 13 Medial elbow flexion contracture caused by a trapezoid form of scar sheet's surface deficit, compensated counter transposed adipose scar trapezoid flaps from scars of the fold involving all flexion medial surface (FM). (A) Contracture caused by the scar fold located amidst medial flexion surface, both fold's sheets are scars and cover entire joint FM surface; planning of trapeze-flap plasty with three pairs of adipose-scars flaps; (B) after several radial Y-incisions of the fold and full contracture release, appearing wounds(scar surface deficit - Dt) and flaps–FP-accepted trapezoid form. (C) ten days after surgery: counter transposed flaps compensated scar surface deficit and contracture eliminated.

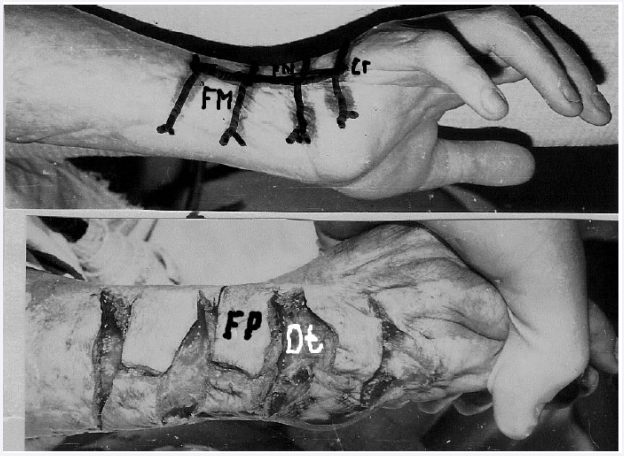

Figure 14 Medial wrist contracture (ulnar hand deviation) caused with trapezoid scar surface deficit of fold's sheets: (upper) semilunar scar fold, planning of three pairs of adipose-scar flaps with Y-shaped radial lines; (lower) radial dissection of the fold caused trapezoid wounds (DT- s car surface deficit) and flaps (FP) in the scar fold's sheets; trapezoid flaps' surface enough for compensate scar surface deficit and fully eliminate the contracture.

axis level. Medial contracture: incision along fold's crest divides flexion medial surface (FM) on two parts or scar sheets. Each of sheets is dissected and separated from flexion lateral surface (FL) with Y-shaped radial/perpendicular incisions. Separating contracted scars from neighboring tissues and perpendicular / radial/ incisions is paramount in the planning of surgery and is shown in Figures 5-21.

Scar surface deficit as real contracture cause

The diagnosis "scar contracture," including knowledge contracture type, the contracture severity, as well as the scars location and degree of spread, do not explain the real surgical anatomic situation and contracture cause. As the contracture cause is scar surface deficit, the main aspect of the reconstruction (planning and choice of technique) is knowledge of the form and size of the scar surface deficit and its location in relation to the contracted joint, commissure and other region of the body. For the efficacious treatment of contracture it is necessary to have correct understanding that contracted scar surface deficit shape is not triangular, but trapezoid. Also joint rotation axis or border with neighboring joint's surface is not equal to zero (in case of edge and medial contractures), but has a linear size in length.

Therefore, for complete contracture release it is necessary to separate the scars of the flexion surface from the scars of extension surface. It can be achieved with linear scar incisions along the fold crest and scar dissection with Y-incision radially and along border with neighboring joint surface joint rotation axis level (T-incision) or with Y-shaped incision of contracted scars. Before the joint rotation axis, the incision is divided45 degrees and extended along the joint rotation axis level to fully promote contracture release, the scar edge divergence and contracture elimination. The end of the wound (scar surface deficit) ranges from 6 mm (commissural contractures, small joints) to 6 cm in big joint.

It is why the local-flap techniques which use the linear incisions of contracted scars should not be utilized. The use of Y-shaped incisions for contracted scar dissection will lead to the trapezoid wound formation. To cover it, the trapezoid flap is needed and trapeze-flap plasty is necessary for scar surface surplus and neighboring healthy skin use to complete the wound resurfacing and elimination of edge and medial contractures. In case of total contractures, the scars' dissection does not have specific form; incisions are directed on complete contracture release. Dependent upon the wound size and local circumstances, the scar surface deficit is compensated for using different methods as the local techniques are not used.

Scar surface deficit causing edge scar contracture: Size and location of scar surface deficit of contracted scars is determined by contracture type anatomy. Edge contractures are characterized by four anatomic features (Figures 1,4-11): (a) contractures are caused with scars, covering joint flexion and commissural lateral (FL) surface;(b) scars, growing distally, form the fold located along the edges of large joint fossa: shoulder, elbow, knee, commissure, edge of ankle anterior surface; first web space (and commissural edge of mouth orifice, inter digital commissure, and neck anterior and lateral surfaces; (c) different quality of the fold's sheets: lateral sheet is scar and is continuation of scar causing contractures; medial sheet and adjacent region is healthy skin; the fold is a new anatomic structure presenting surface surplus of scars and skin allowing contracture treatment with local flaps (Figures 4-11); (d) the fold's crest is edge of the scars (Figures 1,4-11).

Because scar surface deficit is a cause of contracture, its location, size and form are considered in the first step of contracture treatment. Scar surface deficit causing contracture occupies the joint flexion lateral (FL) surface, from the fold's crest to the joint rotation axis level, posterior neck, dorsal hand, and cheek (Figures 4-11). The size and form of the surface deficit is estimated as follows: the scar sheet is separated from the healthy skin with incision along the fold crest. Then, the contracture is released and contracted scars separated from joint extension (E) surface with one perpendicular Y-incision from fold crest to the joint rotation axis, malleoli, or full contraction release if contracture is cervical, truncal, perineal or commissural (microstomia and syndactyly). After joint and neck extension, finger abduction and mouth orifice opening, as a rule, the trapeze-shaped wound is created, reflecting the scar surface deficit form, size and its location (Figures 4-11).

The scar sheet surface deficit (wound) in length is maximal at the fold's crest and spreads, subsiding, to the joint rotation axis, neck, hand, and cheek surface. The trapezoid form (not triangular) of scar surface deficit (the wound) is preserved independent of contracture location and severity and number of incisions. Consequently, the trapezoid flap (not triangular) is needed for wound coverage and scar deficit compensation. The optimal donor site for adequate (trapezoid) flap construction is healthy medial fold's sheet and adjacent undamaged area: joint and commissural fossa, ankle and neck anterior surface. Maximal use of the local (sheets of the fold) and neighboring tissue (flexion medial surface or fossa of big joints, anterior surface of ankle and neck and commissural fossa, serving as donor sites for trapezoid flap elevation) and adequate contracture elimination is achieved with trapeze-flap plasty (Figures 4-11).

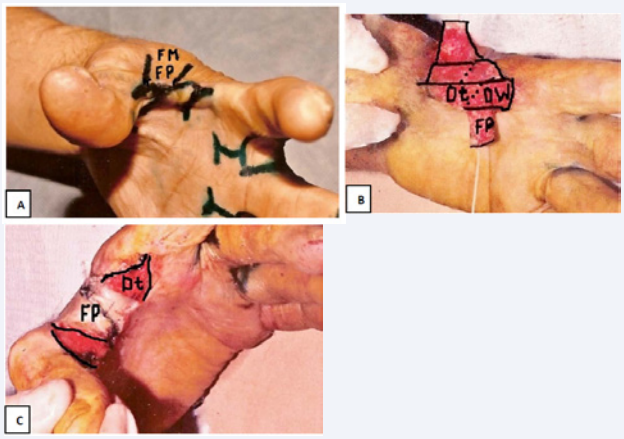

Figure 15 First web space adduction contracture caused by scar surface deficit of scar sheets of the fold. (A) Before operation, scar fold located amidst fossa; planning one pair of trapezoid scar flaps; (B) after two radial incisions of the fold and trapezoid flaps mobilization, two trapezoid wounds and flaps appeared, having common basement. (C) Counter transposed trapezoid flaps formed central zone of first web space; wounds aside flaps are skin grafted.

Scar surface deficit causing medial scar contracture (Figures 12-22)**:** Medial scar flexion contractures are characterized and caused by: (a) scars covering flexion medial surfaces of large joints: axillary, all flexion surface of small joints, elbow, wrist, knee, ankle, first web space, flexion surface of interphalangeal joints, nose, anterior and lateral neck , perineum, and lateral truncal surface; (b) scars form folds located along the medial line of the joint flexion surface, anterior and lateral neck, lateral trunk and perineum and(c) both folds' sheets are scars and have surface deficit in the length, causing contracture, and scar surface surplus in width, allowing the contracture elimination with local flaps (Figures12-22). The form and size of the scar surface deficit is estimated as follows: the fold's sheets are separated with an incision along the fold crest; scar sheets, covering flexion medial surface (FM), are dissected with a perpendicular Y-shaped radial incision which is split 45 degrees to the joint fossa edges or flexion lateral surface (FL) (large joints), joint rotation axis of small joints, and full contracture release on cheek, neck, perineum, and lateral trunk.

The medial contracture is completely released with incision along the fold's crest. Then, a separating every sheet of fold was cross-cut by Y-incisions up to the joint flexion lateral surface of big joints, joint rotation axes of small joint contractures. The contractures located in other region of body are released with Y-incision up to complete contracture release (neck, trunk, and perineum). The appeared wound (scar surface deficit) accepts, as a rule, the trapezoid form in every fold sheet and half of flexion medial surfaces, independent of the number of cross-cut Y-incisions which became visible after contracted region extension (Figures 12-22). Both scar sheets in all extension including the subcutaneous fat layer are converted with radial Y-incisions into adipose-scar trapezoid flaps. Regardless of the number of the incisions, wounds (scar surface deficit) and flaps accept trapezoid form. Since wounds and flaps have trapezoid form, the counter transposition of flaps allows the scar surface deficit compensation, wound coverage and full contracture elimination with a single procedure. Rarely (in case of severe scar surface deficit) the donor wounds need to be covered with skin transplants (Figures 15,16). In conclusion, in case of medial scar contractures the trapeze-flap plasty planning and implementation is simple, easy and safe. It is indicated in early stages of scar maturation in adults and children, with predictably excellent outcomes.

Scar surface deficit of total scar contracture: becomes obvious after the dissection of contracted scars up to the joint rotation axis projection where the end incision is split; additional incisions make wound and scar surface deficits of different sizes and forms, the resurfacing of which necessitates skin grafts, regional pedicle or free flaps (Figures 23).

DISCUSSION

Multiple postburn scar contractures are treated using different surgical techniques, but several important aspects are not yet explored; therefore, surgical rehabilitation of burned patients remains far from perfect. The following aspects of postburn scar contractures require more research: anatomy, classification, contractures' cause (scar surface deficit), and anatomic substantiation of reconstructive techniques. There is very little information about the outcomes that are supported by solid research in relation to anatomic contractures type. Numeric and "name" classifications do not describe specifics regarding anatomic features of contractures; therefore, the list of types of contractures is likely to increase in the future. We have surgically treated thousands of contractures with careful research of their anatomy. Our results indicated that there are only three anatomic forms or types of contractures: edge (most common), medial, and total [5]. Every type has specific clinical and anatomical signs and can be easily diagnosed. Only edge and medial type contractures (nearly 86% of total number) have skin and scar surface surplus and are treated with local flaps. Therefore, the anatomy and scar surface deficit are explored of these two types, and results are presented in this paper. The edge contracture of our classification includes Type I and Type II of all numeric classifications (described below). Medial contractures (16% of total number) are not studied and not presented as a part of any existing classification.

Figure 16 Finger flexion medial contracture caused by scars covered entire joint flexion surface and formed the fold located amidst flexion surface. (A) Before operation, both sheets of the fold are scars, having scar surface deficit (contracture cause), planning; (B) fold's sheets dissected with radial Y- incisions to the joint rotation axis level; trapezoid wounds (scar surface deficit) and flaps appeared which skin grafted are.

Postburn scar contractures classifications

Two methods of scar contracture classifications exist: numeric and name. Numeric classifications -three types [6], four types [7], and more. There are classifications of isolated joint contractures. Numeric classifications concern only two types, edge and total. In numeric classifications, type 1 A and B and Type 11 have the same anatomy. (DELETE next phrase in YELLOW) Edge contractures can have three locations in big joints: flexion lateral anterior, posterior and bilateral (others big joints) and commissural oral (lateral) and inter phalangeal dorsal and palmar. Independent of location, the edge scar contracture has four anatomic features. The medial contractures that comprise nearly 1/3 of total

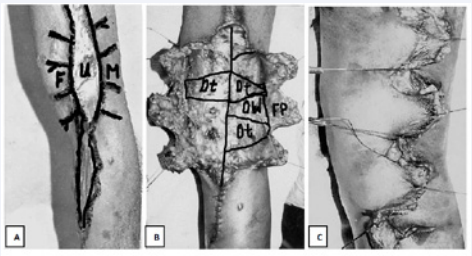

Figure 17 Knee medial flexion contracture caused by fold, both sheets of which are scars and have a trapezoid surface deficit (contracture cause). (A) Before surgery: fold along medial flexion line, both fold's sheets are scars; planning; (B) after radial Y-shaped incisions, trapezoid wounds (scar surface deficit) and flaps appeared: (C) counter transposed flaps covered the wound and compensated scar surface deficit.

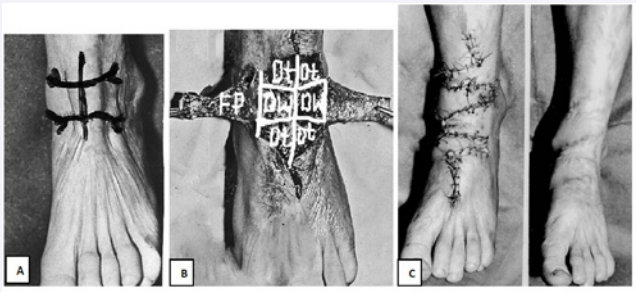

Figure 18 Ankle medial dorsiflexion contracture caused by the scar joint anterior surface and formed fold both sheets of which have surface deficit in length (contracture cause). A – Before surgery, planning reconstruction with Y-shaped lines; B – after radial Y-shaped incisions and trapezoid flaps mobilization, two trapezoid wounds appeared with a common base along the medial line (aside the strip). Dt - deficit, FP-flap, DW-donor wound; (C) two pairs of trapezoid adipose-scar flaps mobilized, counter transposed scar surface deficit compensated and contracture eliminated.

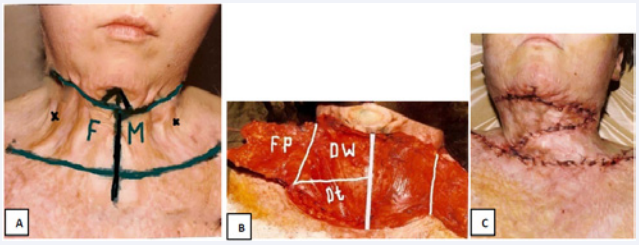

Figure 19 Medial neck anterior contracture caused by the fold located along the cervical medial line; scar sheets of the fold have a trapezoid surface deficit (contracture cause). (A) pre-operative view, planning two trapezoid flaps; (B) after Y-shaped incisions and scar-fascial flap mobilization, two trapezoid flaps and wound appeared (one on every neck side, reflecting surface deficit) sharing a common base (white strip) passing along the medial cervical line; Dt- deficit of scars, DW- donor wound; (C) Severe neck contracture eliminated with transposed flaps.

number takes place on all joints, neck, trunk, perineum, but are not included in the numeric classification system, and therefore, cannot be used.

Except numeric classification, most authors give contractures names according to the external scar's form and degree of spread: linear; wide; wide linear; web straight linear; narrow; long; quadratic; cord like; extended; extensive [8,9]. Obviously, the listed names are not classifications as the name is based one feature of scars (form, spreading).

According our studies, all anatomic features are laid in three group or types: edge (70%% of total number), medial (16%) and total (14%). Every type has specific anatomic and clinical signs and easy diagnosed.

Commonly used reconstructive techniques are based on triangular local flaps and the main technique is Z-plasty. Chan and Donelan [10], write that Z-plasty has found many uses in plastic surgery and is definitely part of every plastic surgeon's armamentarium; and have demonstrated this in their depictions of the treatment of anterior-posterior shoulder scar edge contracture. Asuku [11], concluded that local flaps are sufficient in the treatment all Type I contractures (three-type classification). Huang [12], determined that Z-plasty was not possible in cases with limited availability of healthy skin adjacent to the wound and suggested the use of interposition flap technique instead

Dagra et al. [13], compared results of the treatment of contractures of upper extremity with skin grafting and z-plasty. The mean visual analog score for patient satisfaction was 8.06 for the Z-plasty a group versus 5.33for the split thickness skin grafting group.

For reducing adverse side effects of Z--plasty (incomplete contracture release, flapnecrosis, re-contracture and repeated operations) many combinations were proposed. Sen et al. [14], used a releasing incision and quadra Z technique; Yotsuyanagi et al. [15], double combined Z-plasty for wide-scar contracture release. Zhang et al. described reversed Z-plasty and its variants for release wide-scar contraction [16]. The technique used on 28 patients, all wounds healed well and the scar contracture was satisfactorily released.

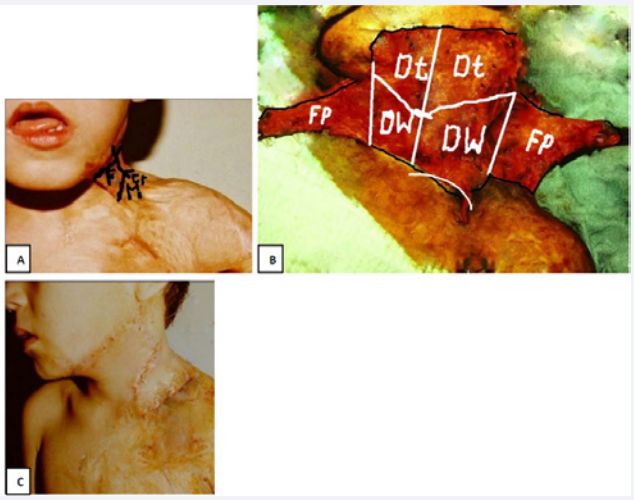

Figure 20 Medial lateral neck contracture caused a scar fold located along the lateral cervical line; in fold's sheet, there is a trapezoid scar surface deficit in length, causing contracture. (A) Before operation, two trapezoid flaps planned; (B) scar-fascial trapezoid flaps mobilized, two trapezoid wounds appeared sharing a common base, contained scar deficit (Dt) and donor wound (DW); (C) oppositely transposed flaps completely restored the neck.

Combination of rhomboid flap and double Z-plasty technique for reconstruction of palmar and dorsal web space burn contractures was presented by Sari et al. [17]. Y-V plasty is rarely used in post burn scar contractures treatment. Suzuki at al. [3] wrote that this technique is one of the most common in plastic surgery and proposed a comprehensive classification of Y-V flaps and their analogs. Flaps can be easily designed according to the degree of contracture and the shape of the scars and that it is useful to combine Y-V flaps with planimetric Z-plasties. Arastech E and Yavari M. [18] used the running Y-V plasty for treatment of linear and cord-like burn contractures. Double reverse Y-V-plasty as a new modification of Y--plasty has been reported [19], and double-opposing Z- and V (K-M-N) plasty [20] has been proposed. A surgical treatment algorithm to achieve significant improvement outcomes has also been proposed [21].

Analysis of literature shows that little objective data concerning outcomes of scar contractures treatment are published. Hop et al. [22], reported that in 13.0% (*n*= 229/1768) of the patients with burns, reconstructive surgery was performed. Mean number of reconstructive procedures per patient were 3.6 (range 1-25, need to include standard deviation). The most important indication was scar contracture; the most applied technique was release plus random flaps and/or skin grafting. Number of repeated operations indicates for two reasons: contracture was incompletely released or serious complications followed reconstruction.

Despite the use of existing techniques, complete restoration of joint function is not achieved. Simon-Williamson et al. [23], analyzed upper extremity motion in children after axillary burn scar contracture release. Improvement in axillary contracture release surgery improves functional shoulder mobility and decreases in compensatory motions were maintained for one year after surgery. Ten years after, authors [24] revealed that all shoulder movements, with the exception of shoulder flexion during the high reach task and shoulder abduction during the hand to back task, were not significantly different than normal values at long-term follow-up.

Buis et al. [25], noticed flap necrosis of flap after Z-plasty is caused by extended sutures placed on of flap's sharp end. In proposed technical modifications for preventing this complication, the tension sutures were placed on base of scar flaps.

Van Niekerk et al. [26], noticed that a success of Y-V plasty depends on the depth of the flap's advancement only, which is restricted as the flaps are not mobilized. Gumus [27], concluded that the Y-technique uses undermined flaps which could not close the defect completely; the deep incision through the fascia makes advancement of the V flap easy by sliding.

Balumuka et al. [28], reported that of 58 patients with shoulder and elbow contractures, 30 (52 %) had a recurrence with 67% being shoulder contracture. The most commonly employed operative technique was the local triangular flap. Complete release of the shoulder contracture was achieved in 56 % of right joint contracture and in 33 % of left joint contractures. Incomplete contracture release resulted in contracture recurrence. Stekelenbur et al. [29], explored the

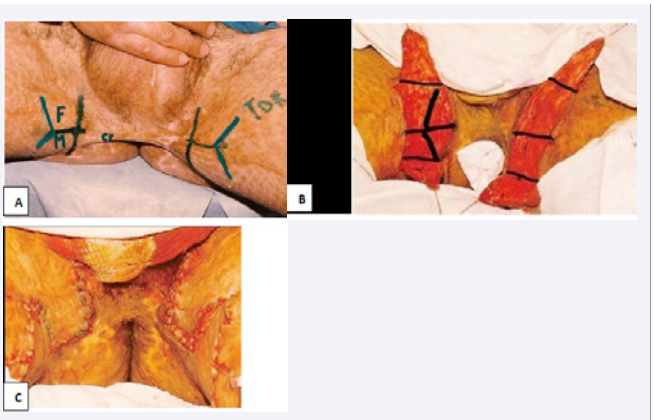

Figure 21 Medial perineal contracture caused by scars of flexion medial surface (FM), which formed a transverse fold; both sheets are scars and have a surface deficit in length (contracture cause) and surface surplus in width. (A) Pre-surgery, planning one pair of flaps on each hip (Y-shaped lines); (B) one pair of trapezoid flaps mobilized aside of perineal raphe; trapezoid wounds appeared sharing a common base; (C) contracture release completely.

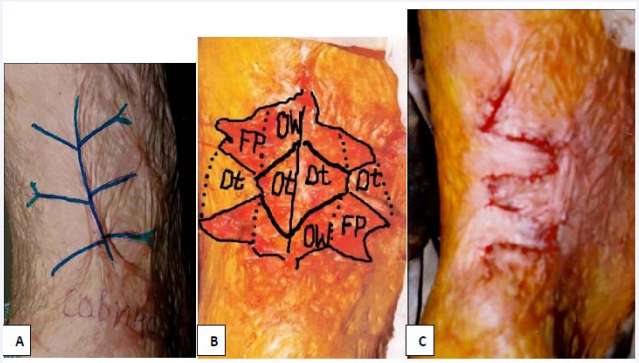

Figure 22 Medial truncal contracture caused by trapezoid scar surface deficiency, treated with two pairs of adipose-scar trapezoid flaps. (A) Medial contracture, both sheets of the fold are scars; planning; (B) fold dissected with radial Y-shaped incisions; after flap mobilization, trapezoid flaps and wounds appeared sharing a common base, reflecting a trapezoid scar surface deficit (Dt); (C) contracture released completely.

efficacy of scar contracture treatment with different techniques and concluded that at present, no consensus exists on the use of kind of technique; no definite conclusions could be reached about the effectiveness of different techniques; therefore, no direct implication for daily practice could be made.

After exploring the rehabilitation level of burned patients, Klein [4], concluded that it is apparent that one should expect an evolution in surgical techniques and technologies that can improve the function and appearance of patients with burn injuries.

As result of the exploration of the anatomy and cause of contracture and after multiple operations using trapezoid flaps and trapeze-flap plasty the authors have made several conclusions.

1. 1.To understand the anatomy and scar surface deficit of existing forms or types of scar contractures, it is

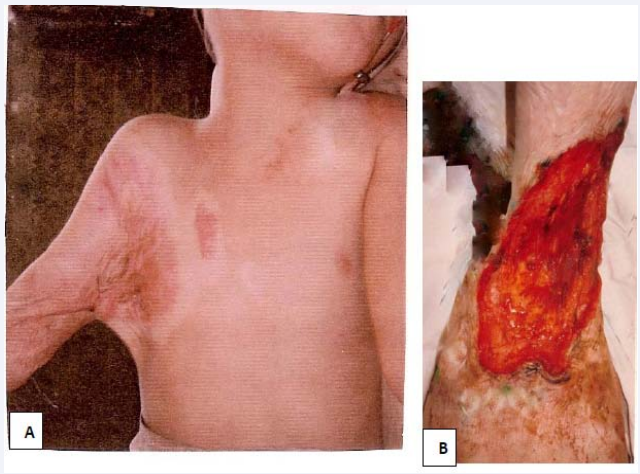

Figure 23 Total shoulder adduction contracture caused in child by severe scar surface deficit excluding local-flap plasty. (A) Total shoulder adduction contracture, pre-surgery; (B) after contracted scars dissection, large wound appeared, reflecting severe scar surface.

necessary to determine the functional zones of the joint's surface. These zones are created by the present joint's fossa and curvature of the surface, borders of zones, and joint rotation axes.

2. Contracture type formation depends on a scar's location, location within a specific joint zone or joint surface of other burned regions of the body.

3. An important anatomic sign indicating possibilities of scar contracture treatment with local flaps is whether the fold along the edges of joint fossa (edge contracture) is present; or (medial contracture) along the midline of flexion medial (FM) surface of small joint and rounded surface of other regions of the body (neck, trunk).

4. Contracted scars with the fold and surface deficit of edge and medial contractures spread over entire joint functional zone, from the fold's crest to the joint rotation axis (edge contracture), and from the fold's crest to the border of neighboring joint's flexion lateral zone/surface (medial contracture).

5. Contracted scars located on specific joint zone/ surfaces are tightly connected with tissue of neighboring zones. For a complete contracture release, contracted scars should first be separated from neighboring healthy tissue from both sides.

6. The following are the consecutive steps of contracture release of edge and medial contractures: an incision along the fold crest;, separation of scars from the other side accomplished together with contracted scar dissection with a Y- shaped radial incision.

7. Dissection of contracted scars isolated from both sides reveals that the wound / scar surface deficit is not absent but has a linear meaning (from 6 mm in commissures to 6 cm in big joints, neck).

8. The presence of scar surface deficit at the end of the contracted zone determines a trapezoid form of the wound and scar surface of all surface deficit appearing after scars dissection with a Y-incision.

9. The presence of scar surface deficit at the border of a neighboring joint zone predetermines a trapezoid form of flaps needed for adequate wound resurfacing and scar surface deficit compensation.

10. In practice, a trapezoid form of scar surface deficit indicates that contracture release should be accomplished with Y-incisions of contracted scars. Since the trapezoid flap matches the scar surface deficit, the trapeze-flap plasty should be used for scar deficit compensation instead of methods based on triangular flaps.

11. Since triangular flaps do not match the scar surface deficit form, the Z-plasty and Y-V technique and all their combinations and modifications are anatomically unsubstantiated and the preference should be given to trapeze-flap plasty.

CONCLUSION

There are three existing scar contracture types: edge, medial, and total. Edge and medial contractures (86% of the total number) form the fold which is skin and scar surface surplus, allowing contracture elimination with local flaps. The joint flexion surface consists of two functional zones: lateral and medial; scars on lateral zone cause edge and flexion medial zone – medial contractures. The contracture is caused by contracted scars having surface deficit in length, appearing as a wound after scar dissection with a Y-incision. Scar surface deficit spreads from the fold's crest to the joint rotation axis (edge contracture), or lateral zones (medial contracture) where the wound (scar surface deficit) does not equal zero, but has a linear size. Therefore, the wound or scar surface deficit has a trapezoid (not triangular) form. The true size of the scar and its form are apparent after the isolation of the contracted scars from both sides, from neighboring tissues with incisions along the fold crest, and a Y-shape incision dissecting the scar and an elongation Y-incision along the neighboring zone. After these incisions, as a rule, the wound or scar surface deficit accepts a trapezoid form because the end of the wound has a linear meaning. The anatomic data indicates that edge and medial contractures (nearly 86% of the total number) should be treated with similar trapezoid flaps and trapeze-flap plasty. Edge contracture is eliminated with a main trapezoid flap, prepared from neighboring healthy tissue and skin sheet of the fold. The donor wounds adjacent to the flap are covered by trapezoid flaps from the scar fold. Medial contracture is eliminated by conversion of the fold's sheets with a Y- radial incision into a trapezoid adipose-scar flap, the surface of which is sufficient for complete contracture elimination. The new flap and plasty methods were tested when treating thousands of contractures. The achieved results allowed for a conclusion that the problem of treatment of most scar contractures with local trapezoid flaps and trapeze-flap plasty had been solved and the rehabilitation of burned patients with scars contractures improved significantly. Local triangular flaps do not match the wound and scar surface deficit and do not completely compensate for scar surface trapezoid deficit. The

authors are convinced that the further use of Z- and Y-V plasty in postburn scar contractures treatment is unjustified.

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