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ORIGINAL ARTICLE

Z-PLASTY – BASIC SURGICAL TECHNIQUE FOR POST-BURN PATIENTS

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Abstract. Background: *In the majority of patients, the consequences of burns often require surgery due to complications like contracture. Various surgical techniques are employed for correction, including free skin grafting, local tissue plasty, and free flaps. This study focuses on Z-plasty as a surgical technique for correcting scar deformities after burns.* ***Materials and Methods:*** *We treated 84 patients with burn consequences. Z-plasty was the main method for 67 patients, while 17 patients received Z-plasty combined with other techniques: 11 with split-thickness skin grafts, 4 with non-free skin plasty, 1 with a combination of Z-plasty, tissue expander, and local tissue plasty, and 1 with two different Z-plasty sites.* ***Results:*** *Early complications occurred in 8 patients. One case resulted in inflammation and dehiscence of the plasty. In 6 cases, partial lysis of the vertices of the triangles was observed, which healed spontaneously.* ***Conclusions:*** *Despite some early complications, Z-plasty proves to be a successful treatment method for scar deformities post-burn. The results are generally satisfactory, demonstrating the efficacy of this technique in most cases.*

Key words: *Z-plasty, burns, post-burn contracture, surgical treatment*

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INTRODUCTION

In 40-60% of burn patients, scars that necessitate treatment are formed. Among these, 40% of children develop scar contractures, which present primarily as functional impairments rather than merely cosmetic issues [1]. The most severe complications resulting from burns are contractures [2]. Their treatment is primarily surgical, often supplemented with conservative methods that serve as adjunctive therapies [3]. Z-plasty, both as a standalone technique and in combination with other surgical methods, is widely utilized as a treatment of choice for patients with hypertrophic scars and keloids following burns.

MATERIALS AND METHODS

The study focused on 95 out of the 431 patients with burn sequelae treated at the Department of Plastic,

Reconstructive, and Esthetic Surgery at University Hospital "Sv. Georgi" – Plovdiv, for eight years. Z-plasty was employed as the primary surgical method in 58 (61.05%) patients and in combination with another surgical technique – in 22 (23.15%) patients. Among these patients, 52 (54.73%) presented with contractures. We evaluated the outcomes of the surgical techniques based on factors such as gender, age, defect location, presence of keloids, contractures, syndactyly, and length of hospital stay.

RESULTS

All surgeries were successfully completed. Venous congestion occurred in 13 patients within the first three days post-operation and resolved without additional interventions. Epidermolysis at the flap tip occurred in 4 patients and was healed through guided spontaneous epithelialization. The long-term results were very good. There were 2 cases of partial wound dehiscence: one in the popliteal fossa and the other in the axilla. The cause of dehiscence in the popliteal fossa was a secondary infection, while in the axilla, it was due to acute bleeding. Both cases were reoperated on with satisfactory outcomes.

Age Distribution

The gender distribution among the patients was 60 males (63.2%) and 35 females (36.8%), mirroring the typical gender ratio seen in acute burn cases. The patient ages ranged from 10 months to 78 years. Children aged 4-10 years made up nearly one-third (30.5%) of the cohort (Table 1). The remaining age groups were relatively evenly distributed, with the fewest patients being over 65 years old (Table 1).

Table 1. Age Distribution

Age (years)	Frequency (n)	Percentage (%)
0-3	11	11.6%
4-10	29	30.5%
11-18	15	15.8%
19-35	17	17.9%
36-65	18	18.9%
Over 65	5	5.3%
Total	95	100%

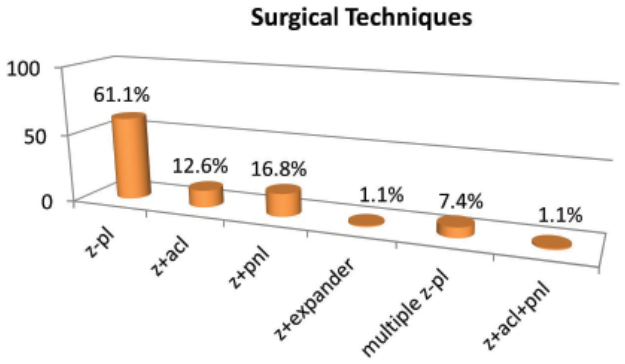
Hospital Stay Distribution

The hospital stays were categorized into 3 groups: short (up to 5 days) with 44 patients (46.3%), medium (5-10 days) with 32 patients (33.7%), and long (over 10 days) with 19 patients (20.0%). A statistically significant difference was observed in patients who underwent Z-plasty, with 77.3% experiencing a short hospital stay ($P < 0.05$, $\chi^2 = 30.102$).

Operation Technique Distribution

The distribution of operation techniques is shown in Table 2. The surgical methods included single Z-plasty, multiple Z-plasties, Z-plasty combined with free skin grafting (autoplastica cutis libera – ACL), expander techniques, and Z-plasty combined with adjacent flap techniques, which we categorized as non-free skin grafting (plastica non libera – PNL).

Table 2. Distribution by types of operations



Note: Z-pl = Z-plasty, Z + ACL = Z-plasty + autoplastica cutis libera, Z + PNL = Z-plasty + plastica non libera, Z + expander = Z-plasty + expander technique, Z + ACL + PNL = Z-plasty + autoplastica cutis libera + plastica non libera.

We diagnosed contractures in 52 patients (54.73%), syndactyly in 17 patients (17.9%), and keloids in only 4 cases (4.2%). Contractures were twice as common in males (71.7%) ($p < 0.05$, $\chi^2 = 18.840$). Notably, 34 patients (65.38%) with contractures were children, while only 18 (34.62%) were adults.

The distribution of surgical techniques for contractures is shown in Table 3. Without statistically significant differences, but with a clear advantage, the single Z-plasty and variations of local flaps are the main operative techniques for correcting contractures with various localizations. Syndactylies are equally distributed between males and females. In cases of syndactylies, children comprise 12 cases (70.58%), while adults comprise only 5 cases (29.42%).

Table 3. Surgical Technique for Contractures

Surgical Technique	Contracture	Total Patients
Z+ACL	6 (11.5%)	12 (12.6%)
Z+PNL	11 (21.2%)	16 (16.8%)
Z+PNL+expander	0 (0.0%)	1 (1.1%)
Z+Z	2 (3.8%)	7 (7.4%)
Z	32 (61.5%)	58 (61.1%)
Z+PNL+ACL	1 (1.9%)	1 (1.1%)
Total	52 (100%)	95 (100%)

Note: Z = Z-plasty, Z + ACL = Z-plasty + autoplastica cutis libera, Z + PNL = Z-plasty + plastica non libera, Z + PNL + expander = Z-plasty + plastica non libera + expander technique, Z + PNL + ACL = Z-plasty + plastica non libera + autoplastica cutis libera.

Fig. 1. Contracture of the hand: pre-operative image

Fig. 2. Contracture of the hand: post-operative image

The distribution of keloids by gender favors women (75%). Keloids occur in childhood in 74% of cases, with localization on the upper limb in two cases, one on the lower limb, and one on the body. Similar to contractures, the most affected age group is between 4-10 years old.

For all keloids, a single Z-plasty with displacement of adjacent flaps was used. There is a statistically significant relationship between age and localization in operations on the upper limb ($p < 0.05$, $\chi^2 = 11.753$). As age increases, the likelihood of forming hypertrophic scars on the hand decreases.

The primary surgical technique is the single Z-plasty, which was applied simultaneously on both hands in 12 cases (20%). Children outnumber adults in age distribution.

Localization Distribution

The distribution of defect localizations is shown in Table 4. The relationship between localization and the type of surgical technique is in favor of the single Z-plasty (77.89%), followed by a combination with local flaps (28.42%), and multiple Z-plasty (18.94%). The combination of Z-plasty and skin autotransplantation ranks second in usability for limb surgeries.

For the remaining localizations, there is no statistically significant difference related to age. In cases of facial defects, individuals in the active age group of 36-65 years predominate ($p < 0.05$). In operations involving multiple localizations simultaneously, 68.2% involve single and multiple Z-plasty ($p < 0.01$, $\chi^2 = 22.987$). Most commonly, these involve both upper limbs. Men are more prevalent in these cases.

In patients over 65 years old, scar deformations on the neck are predominant ($p < 0.01$, $\chi^2 = 16.556$). In this age group, 60% of patients have contractures.

We applied Z-plasty independently in 46.2% of neck contractures across all age groups, and in combination with local flaps in 30.8% ($p < 0.05$, $\chi^2 = 11.964$).

Facial lesions are mainly observed in the active age group of 36-65 years old ($p < 0.05$, $\chi^2 = 15.673$) and represent 33.3% of scar defects in this age group. For the remaining localizations, we did not find a statistically significant difference.

Combined techniques mainly involve combinations of Z-plasty with ACL and PNL. These combinations are predominantly used in adults, where more extensive defects are observed. ACL is primarily used to cover donor areas and for extensive scar excision, while PNL is used to cover functional areas with adjacent flaps.

The difference is statistically significant in surgeries on the torso as well. In 69.3% of cases, we performed single and multiple Z-plasty, while 23.1% involved a combination with adjacent flaps. ($p < 0.05$, $\chi^2 = 13.407$).

Table 4. Distribution According to Localization

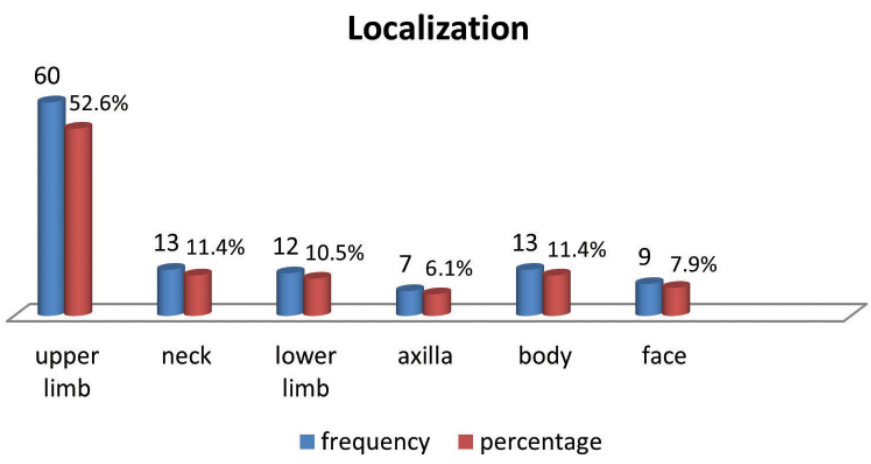


Fig. 3. Case with Multiple Z-plasty – pre-operative image

Fig. 4. Case with Multiple Z-plasty – post-operative image

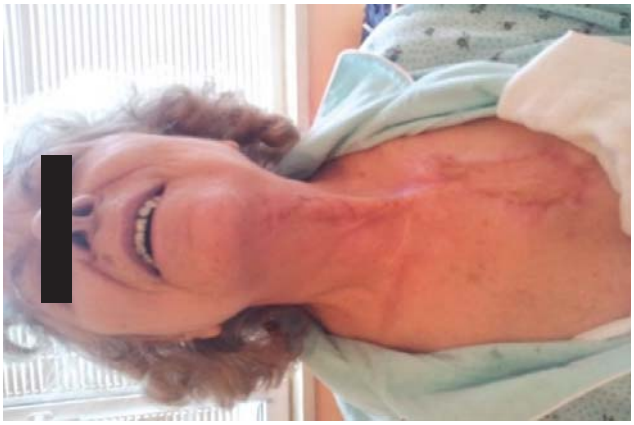


Fig. 5. Case with Multiple Z-plasty – pre-operative image

Fig. 6. Case with Multiple Z-plasty – post-operative image

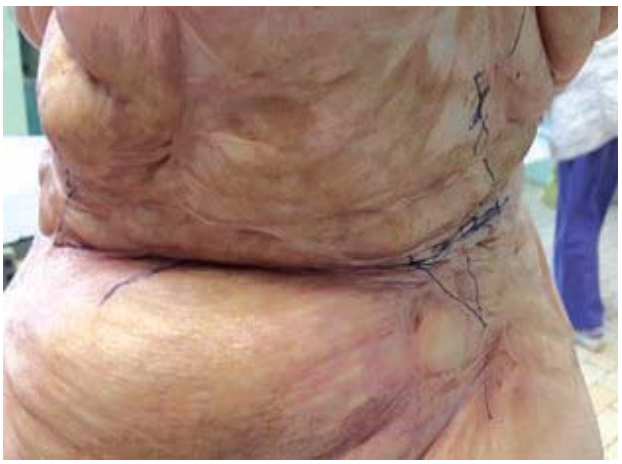


Fig. 7. Case with Asymetrical Z-plasty – pre-operative image

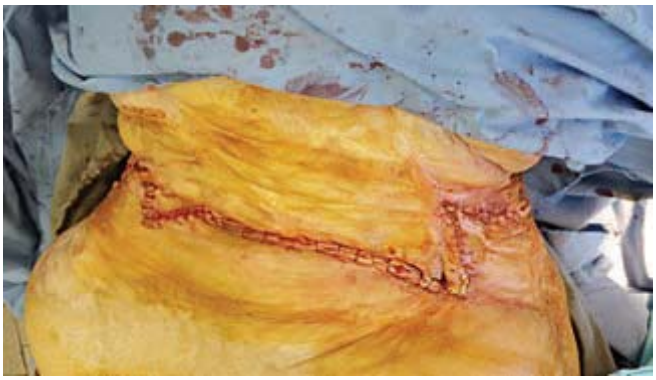


Fig. 8. Case with Asymetrical Z-plasty – post-operative image

Fig. 9. The same case with Asymetrical Z-plasty – post-operative image

Fig. 10. Limberg's Z-plasty – pre-operative image

Fig. 11. Limberg's Z-plasty – early post-operative image

Fig. 12. Limberg's Z-plasty – late post-operative images

In the operative interventions of the cases we reviewed, we utilized various modifications of Z-plasty: single and multiple Z-plasties, Z-plasty with symmetric figures, asymmetric figures with triangles of different angles. All patients underwent surgery under general anesthesia. For single and multiple Z-plasties, we made longitudinal incisions along the direction of the scar, which coincided with the short diagonal in single Z-plasty. In most cases, we used triangles with equal sides and angles of 60°, i.e., symmetric figures. Multiple Z-plasty and those involving the formation of local flaps were mainly used for axillary and torso contractures.

In some patients, we performed excision of the bridge and available scar tissue. In other cases, complete removal of scar tissue was not possible due to its significant involvement of surrounding tissues. For example, in cases of local flaps with limited skin resources due to extensive deformations, we used relaxing perpendicular to the skin incisions. Z-plasty was applied for contractures of major joints and massive bridges. These were mainly patients with extensive deformities and changes in the anatomy of entire body areas. We used rotational, advancing, and transpositional flaps, taking into account the size of the defect and compromised surrounding tissues. In most cases, these tissues had reduced elasticity and decreased the range of motion of the flap. Rotational flaps were applied in areas such as the nose, advancing on the neck with the formation of Buerger triangles at the base, transpositional on major joints, etc. When forming flaps, we considered the elasticity and blood supply of the surrounding tissue and the potential volume of rotation.

The expander technique was applied to one patient with the placement of two rectangular expanders above the mammary glands to cover the neck and face (Fig. 13).

Both expanders were placed with incisions in areas of potentially least tension – parasternal in the subfascial plane. They were gradually filled over two months, followed by covering rough scars on the neck and face.

DISCUSSION

Z-plasty is a surgical technique in which adjacent tissue flaps are exchanged, united by an incision in a common shape. According to McGregor, Z-plasty is the most commonly used method for treating burn sequelae [3], particularly in correcting contractures. This is confirmed by our observation: of 52 patients with contractures, 32 were operated on solely with Z-plasty, while 11 underwent a combined approach with local flaps.

Z-plasty is historically associated with Horner (1837) and Denonvilliers (1856), who empirically used the technique. Limberg's scientific works established that flap plastic surgery follows certain regularities

Fig. 13. Case with expanders

[4]. This technique interrupts tension lines in the scar, protects against contractures, and is used to reposition insufficient tissue in a given area. Suzuki suggests that in concave skin surfaces with greater skin tension, Z-plasty should be performed along the length of the bridge to reduce tension [5]. Even with angles greater than 90°, the normal elasticity of the skin can eliminate cones [6]. In our study, we observed elongation with single and multiple Z-plasties, even without lateral relaxing incisions. On concave or protruding surfaces, cones may decrease or disappear if they correspond to the surrounding structure's relief. However, in extensive scar changes, cone formation was unavoidable, necessitating subsequent removal [7].

In reconstructive surgery, adjacent tissues must be treated regardless of the surgical method. The surgical approach should be planned based on the defect's shape, irrespective of its location. Perez-Bustillo believes that irregular-shaped scars are less noticeable than linear ones from an esthetic standpoint [8]. We support this view and find that interrupting the bridge line and applying Z-plasty with 60° angles and equal sides yields good esthetic results due to even tension distribution. For longer bridges, multiple Z-plasties are preferred.

A single rhomboid flap Z-plasty has a greater elongation coefficient compared to multiple Z-plasties and requires fewer incisions, resulting in fewer scars [9]. In our study, single Z-plasties were significantly more common than multiple ones, supporting the claim of fewer scars. The formation of opposing triangular flaps, combined with adjacent flaps, often preserves part of the scar tissue but helps overcome long bridges and severe flexion contractures. We agree with Suzuki that recurrences with this technique are fewer.

Variations of the classic Z-plasty with 60° angles can be performed for mild contractures, with angle changes to 75° and longer side incisions than the base [10, 11]. We used symmetric Z-plasty for small-volume scars, but for more severe bridges, we increased the central diagonal's length while reducing the sides' size and angle degree. Like Suzuki, we cut the defect along with the underlying connective tissue and then sutured it [5].

To avoid necrosis, a fundamental rule is not to thin the flaps. If relaxing incisions are needed, they should not be medial to the flap's base. Stitching without tension is crucial for the flap's survival. We achieved this by removing part of the fat and fibrous tissue while preserving the feeding vessels [12].

For closing rhomboid defects, a figure with 60°-120° angles, known as the Limberg flap [4], can be used. There are various modifications, such as the Dufourmentel flap [13]. In these cases, one incision is placed on the defect's edge. A modification of this method makes the transferred flap smaller, relying on the skin's extensibility to compensate for size [14].

U-shaped scars have a centrally elevated ridge. By forming one or two Z-plasties at the base, the scar's appearance can be improved [15]. These "trap-neck" scars impede lymphatic flow, and by cutting them with opposing triangular flaps, the exchange surface is increased, leading to a good final result. We agree with Furnas that the goal of releasing the contracture is not only elongation but also shaping the interrupted bridge to prevent recurrence [16].

For corrections of the chest and arms to change the scar's direction, we used a series of unrelated single Z-plasties, with central incisions parallel to skin tension lines. We agree with Fader that with this technique, one side of the figure becomes almost imperceptible as it fits into a natural skin fold [17].

Complex asymmetric figures are used according to available skin resources. As a rule, the angles differ, but the sides' lengths are equal. This rule may be violated when there is an abundance of skin on one side of the defect. Examples include V-Y plasty and its combinations, such as double V-Y plasty, Burow's method with triangular excisions, and combinations with transpositional flaps [18, 19].

In correcting syndactyly, we used a series of Z-plasties with asymmetric figures, providing excellent elongation when surrounding tissue is available. Syndactyly is a common childhood defect; 8 out of 17 of our patients were between 4-10 years old. Single Z-plasty was the primary surgical technique, with STAR-plasty, VM-plasty, YV-plasty, and others used for syndactyly of the first commissure [20, 21].

CONCLUSIONS

Z-plasty continues to be a primary surgical method in reconstructive surgery. Although the surgical technique may vary among different patients, understanding the basic principles of Z-plasty allows the surgeon to find an optimal solution for correcting the sequelae of burns. The advantage of this method lies in its ability to be combined with other surgical approaches, which justifies its frequent use and good final results. Despite its advantages, the plastic surgery with opposing triangular flaps still has a number of limitations: a higher number of incisions in this method results in more scars. This method is suitable for improving functional activity in the area of the defect, at the cost of an unsatisfactory esthetic result.

Advantages of Z-plasty variations:

1. The single-stage method is appropriate, even as a first choice for children
2. Effective for contractures and syndactyly, even mild and severe ones
3. Better redistribution of skin tension while protecting large vessels
4. Forms a more esthetic scar by hiding part of the flap in anatomical folds
5. Easily combined with autoplastic techniques in case of tissue deficiency.
6. Allows quick rehabilitation, short dressing period and low riks of recurrence.

Disadvantages:

1. More flaps result in more scars
2. Tip necrosis may occur with small triangles
3. Scarred tissue is more difficult to rotate
4. Excessive increase in the closing angle may result in “cones,” requiring subsequent correction.

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Informed Consent from Participants: *Informed consent was obtained from all participants included in the study.*

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