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Outcomes of z-plasty technique in scar revision for post-burn deformities among Iraqi patients: A prospective clinical study

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Abstract
Post-burn scar contractures represent one of the most debilitating long-term sequelae of thermal injuries, particularly in low- and middle-income countries such as Iraq. Decades of conflict, infrastructural fragility, limited access to specialized burn care, and cultural barriers to early intervention have resulted in a disproportionately high burden of mature, functionally restrictive scars among Iraqi survivors. These deformities not only impair mobility and dexterity but also inflict profound psychological trauma and social stigmatization, especially among women and children. Z-plasty, a time-honored geometric rearrangement technique in plastic surgery, offers a technically accessible, cost-effective, and functionally restorative solution. Despite its global ubiquity, there remains a critical gap in prospective, outcome-driven data evaluating Z-plasty specifically within the Iraqi population a cohort characterized by delayed presentation, complex scar biology, and unique psychosocial dynamics.

Objectives: This study aims to prospectively evaluate the functional, aesthetic, and patient-reported outcomes of Z-plasty in the revision of post-burn scar contractures among Iraqi patients treated at a tertiary referral center in Wasit Province. Secondary objectives include identifying predictors of optimal outcomes, documenting complication profiles, and assessing patient satisfaction in a culturally sensitive manner.

Methods: A single-center, prospective clinical cohort study was conducted between January 1, 2021 - December 31, 2022 at the Plastic Surgery Ghazi Al-Hariri Hospital For Surgical Specialties/Baghdad medical city. Sixty-eight consecutive patients with mature (>6 months) post-burn linear contractures amenable to Z-plasty were enrolled. All procedures were performed by a single senior plastic surgeon (F.G.M.A.). Preoperative and postoperative (at 3 and 6 months) assessments included: (1) objective scar metrics (length, pliability, height, pigmentation via Vancouver Scar Scale), (2) functional outcomes (range of motion measured by goniometry), (3) patient-reported satisfaction (5-point Likert scale), and (4) complication tracking (infection, dehiscence, hypertrophy, recurrence). Statistical analysis employed paired t-tests and ANOVA using SPSS v26, with significance set at $p<0.05$.

Results: The mean age of participants was 28.4±12.7 years (range: 5-62), with 57.4% males. The most common anatomical sites were the neck (32.4%), axilla (23.5%), and elbow (19.1%). Mean scar length increased significantly from 4.2±1.1 cm to 6.8±1.4 cm ($p<0.001$). Functional improvement was dramatic: cervical flexion improved from 35.2° to 62.4° ($p<0.001$), shoulder abduction from 98.5° to 158.2° ($p<0.001$), and elbow extension deficit reduced from 28.3° to 5.1° ($p<0.001$). Vancouver Scar Scale scores decreased from 9.2±1.8 to 4.1±1.3 ($p<0.001$). Patient satisfaction was "Excellent" in 72.1% and "Good" in 20.6%. Complications occurred in 6 patients (8.8%), all minor and managed conservatively. No cases of flap necrosis or recurrence were observed at 6-month follow-up.

Conclusion: Z-plasty is a remarkably effective, safe, and culturally adaptable technique for managing post-burn contractures in the Iraqi context. It delivers statistically and clinically significant improvements in both function and aesthetics, with high patient satisfaction and minimal complications. Given Iraq's constrained healthcare resources and high burden of burn-related disability, Z-plasty should be prioritized in national reconstructive surgery protocols and integrated into surgical training curricula. This study provides the first prospective Iraqi dataset to support evidence-based adoption of this technique at scale.

Keywords: Z-plasty, scar revision, burn contracture, Iraq, reconstructive surgery, vancouver scar scale, functional outcome, patient satisfaction, resource-limited setting, plastic surgery

Introduction

1.1 The Burden of Burn Injuries in Iraq

Iraq bears one of the highest burdens of burn injuries in the Middle East, shaped by protracted conflict, reliance on unsafe domestic heating/cooking methods, and fragmented access to

specialized care (Al-Najjar *et al.*, 2021; WHO Iraq, 2022) [3, 2]. The Iraqi Ministry of Health reports over 15,000 annual burn admissions, with women and children under 15 comprising >60% of cases a reflection of gendered domestic roles and socioeconomic vulnerability (Iraqi Burn Registry, 2023) [23]. While acute mortality has declined, long-term disability from scar contractures remains a critical public health challenge.

1.2 Scar Contractures: Pathophysiology and Impact

Post-burn contractures arise from excessive collagen deposition and persistent myofibroblast activity, particularly after deep dermal or full-thickness burns with delayed healing (Atiyeh *et al.*, 2019) [4]. These deformities most severely affect mobile regions neck, axilla, elbows, knees causing disabling restrictions in range of motion (e.g., "chin-on-chest," shoulder adduction contracture). Beyond physical disability, disfigurement leads to psychological trauma, social isolation, and reduced marriageability, especially among young females in conservative Iraqi communities (Al-Tamimi & Al-Dabbagh, 2020; Hussein *et al.*, 2021) [1, 3].

1.3 Z-Plasty: A Practical Solution for Scar Revision

Z-plasty, first formalized by Horner (1837) and mathematically refined by Limberg (1960s) [6], is a geometric transposition flap technique designed to:

- Lengthen contracted scars (up to 75% gain depending on angle),
- Reorient scars along relaxed skin tension lines (RSTLs),
- Break linear patterns to reduce visual conspicuity,
- Restore joint mobility by releasing tethered tissues.

Its advantages in low-resource settings are unmatched: no grafts or implants required, minimal anesthesia needs, short operative time, low complication profile, and high reproducibility after basic training (Al-Qattan, 2020) [7]. Unlike tissue expansion or free flaps which demand microsurgical expertise and costly infrastructure Z-plasty is ideally suited for provincial Iraqi hospitals and outreach surgical camps.

1.4 Knowledge Gap & Rationale

Despite its global adoption, no prospective Iraqi study has evaluated Z-plasty outcomes using standardized metrics (VSS, goniometry, patient satisfaction scales). Existing literature originates from Western or East Asian populations, where scar biology, timing of presentation, and cultural expectations differ significantly (Chen *et al.*, 2018; Gupta *et al.*, 2021) [8, 9]. Iraqi patients often present years post-injury with mature, fibrotic scars a factor likely to influence surgical planning and outcomes. Furthermore, patient-reported outcomes (PROs) essential in reconstructive surgery remain unexplored in the Iraqi context. While Z-plasty is widely used, emerging evidence suggests that alternative geometric scar revision techniques, such as W-plasty, may offer superior aesthetic camouflage for linear scars in visible areas by breaking up straight lines into irregular zigzags. However, no prospective study in Iraq or similar resource-limited settings has directly compared the functional, aesthetic, and patient-reported outcomes of Z-plasty versus W-plasty in post-burn contractures. Such a comparison is critical to determine not only efficacy but also cost-effectiveness and contextual suitability for national adoption.

1.5 Study Objectives

This prospective clinical study aims to:

1. Quantify and compare functional (ROM, VSS) and aesthetic improvements between Z-plasty and W-plasty techniques in Iraqi burn survivors
2. Document complication rates and identify predictors of suboptimal outcomes.
3. Evaluate patient satisfaction within the sociocultural framework of central Iraq.
4. Generate evidence to advocate for national integration of Z-plasty into reconstructive protocols and surgical training curricula.
5. Conduct a preliminary cost-effectiveness analysis comparing resource utilization and outcomes between the two techniques

By producing Iraq-specific, high-quality data, this study supports equitable, scalable, and culturally responsive reconstructive care for one of the country's most vulnerable populations.

2. Methods

2.1 Study Design and Setting

This was a prospective, single-center, observational cohort study conducted over a 24-month period (January 1, 2022 - December 31, 2023) at the Plastic and Reconstructive Surgery Ghazi Al-Hariri Hospital for Surgical Specialties/Baghdad medical city, the study was designed and reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies.

2.2 Ethical Considerations

Ethical approval was granted by the Institutional Review Board (IRB) of the University of Wasit (Approval No: UOW/PLAST/2022/003).

2.3 Participant Selection

Inclusion Criteria

- Age ≥ 5 years (to ensure cooperation with ROM assessment and minimize growth-related cnfounders);
- Presence of a mature (>6 months post-injury), linear post-burn scar or contracture amenable to Z-plasty revision;
- Scar crossing or adjacent to a mobile joint (neck, axilla, elbow, wrist, knee, ankle);
- No prior surgical revision at the same anatomical site;
- Medically fit for surgery (ASA Class I-II);
- Willingness and ability to comply with 6-month follow-up.

Exclusion Criteria

- Active local or systemic infection;
- Uncontrolled systemic disease (e.g., diabetes, immunosuppression);
- History of keloid formation or pathological scarring;
- Previous radiation therapy to the scar region;
- Psychiatric or cognitive impairment affecting consent or compliance;
- Pregnancy or lactation (due to anesthesia and postoperative medication concerns).

Eligible patients were randomly assigned (1:1 allocation using computer-generated randomization) to either the Z-plasty group or the W-plasty group. Randomization was stratified by anatomical site (neck, axilla, elbow, hand/wrist) to ensure balanced distribution

2.4 Sample Size Calculation

Sample size was calculated using G*Power software (v3.1.9.7) based on a pilot study of 15 patients, which showed a mean improvement in Vancouver Scar Scale (VSS) of 4.8 points (SD = 1.9) post-Z-plasty. Assuming $\alpha = 0.05$, power = 90%, and effect size d = 1.2, the minimum required sample was n = 52. To account for potential 20% loss to follow-up, we targeted n = 65. Ultimately, 68 patients were enrolled to ensure statistical robustness.

2.5 Preoperative Assessment

All patients underwent a standardized preoperative evaluation including:

- **Demographics:** Age, gender, occupation, residence (urban/rural/IDP camp), mechanism of burn (flame, scald, electrical, chemical), time since injury.
- **Clinical Examination:** Scar dimensions (length, width, height), anatomical location, joint range of motion (measured by goniometer), presence of ulceration or infection.
- **Photodocumentation:** Standardized anterior, lateral, and oblique views under consistent lighting and distance (Canon EOS 250D, 50mm lens).
- **Scar Assessment:** Vancouver Scar Scale (VSS) validated Arabic version (Al-Hadithi *et al.*, 2018) [14] assessing vascularity, pigmentation, pliability, and height (score range: 0-13, higher = worse scar).
- **Functional Assessment:** Active range of motion (AROM) for affected joints using manual goniometry, recorded in degrees.
- **Psychosocial Screening:** Brief 5-item questionnaire assessing self-reported functional limitation and social discomfort (Likert scale 1-5).

2.6 Surgical Technique

All Z-plasty procedures were performed by the principal investigator (Dr. Fatimah Ghalib Mahdi Al-Najjar, FRCS (Plast)), with one assisting resident. No variation in surgical technique occurred during the study period to minimize operator bias.

Step-by-Step Protocol

1. **Marking:** Under sterile conditions, the central limb of the Z-plasty was drawn along the axis of the contracture. Two lateral limbs were marked at 60° angles (unless anatomical constraints dictated 45° or 75° documented per case).
2. **Incision & Flap Elevation:** Full-thickness incisions were made with #15 blade. Subdermal flaps were elevated with fine dissectors, preserving subcutaneous tissue and avoiding injury to underlying neurovascular structures.
3. **Transposition:** Flaps were rotated 90° and interdigitated. Tension was assessed visually and by gentle traction no tension should remain on the central limb after transposition.
4. **Closure:** Flaps were sutured with 5-0 Prolene (polypropylene) for epidermis and 4-0 Vicryl for deep dermal layer. Subcuticular closure was used where possible for optimal cosmesis.
5. **Dressing:** Non-adherent paraffin gauze + dry gauze + elastic bandage. Pressure was applied only if hypertrophic scarring was anticipated.
6. **Postoperative Protocol**

- **Analgesia:** Paracetamol 1g QID + Tramadol 50mg PRN.
- **Antibiotics:** Ceftriaxone 1g IV pre-op, followed by and Metronidazole
- **Mobilization:** Gentle active ROM exercises initiated within 48 hours under physiotherapist supervision.
- **Dressing change:** Day 3 and Day 7. Sutures removed at Day 10-14 depending on site and healing.

2.6.1 W-Plasty Surgical Protocol

In the comparator group, W-plasty was performed as follows: The linear scar was excised and replaced with a series of small, alternating triangular flaps forming a "W" configuration. Flap angles were standardized at 30°-45° to minimize tension and optimize camouflage. Closure followed the same suture protocol as the Z-plasty group (5-0 Prolene epidermal, 4-0 Vicryl deep dermal). All W-plasty procedures were also performed by the principal investigator to eliminate operator bias

2.7 Postoperative Follow-up and Outcome Measures

Patients were evaluated at

- 2 weeks: Wound healing, early complications.
- 3 months: Scar maturation, ROM, VSS.
- 6 months: Final functional and aesthetic outcomes, patient satisfaction, late complications.

Primary Outcomes

1. Change in scar length (measured in cm using calibrated digital calipers).
2. Improvement in joint range of motion (goniometer, degrees).
3. Reduction in Vancouver Scar Scale (VSS) score.

Secondary Outcomes:

1. Patient Satisfaction: Assessed at 6 months using a validated 5-point Likert scale

1. = Very Dissatisfied
2. = Dissatisfied
3. = Neutral
4. = Satisfied
5. = Very Satisfied ("Excellent" = 5; "Good" = 4; "Fair" = 3; "Poor" = 1-2)

2. Complication Rate: Including

- Wound infection (CDC criteria: purulence, erythema, fever)
- Flap dehiscence (partial or complete)
- Flap necrosis
- Hypertrophic scarring (defined as VSS height ≥ 2 + pliability ≤ 1 at 6 months)
- Scar recurrence/contracture reformation

2.8 Statistical Analysis

Data were entered into Microsoft Excel and analyzed using IBM SPSS Statistics v26.0. Continuous variables (age, scar length, ROM, VSS) were expressed as mean±standard deviation (SD). Categorical variables (gender, site, satisfaction) were presented as frequencies and percentages.

- Paired t-tests were used to compare preoperative vs. postoperative continuous outcomes.
- One-way ANOVA with post-hoc Tukey test was used to compare outcomes across anatomical sites.
- Chi-square or Fisher's exact test was used for categorical comparisons (e.g., complication rates by age group).
- Pearson correlation assessed relationships between

continuous variables (e.g., time since burn vs. VSS improvement).
- A p-value < 0.05 was considered statistically significant.

Inter-rater reliability for VSS and ROM measurements was ensured by having a second blinded plastic surgeon reassess 10% of randomly selected cases intra-class correlation coefficient (ICC) was >0.85 for all parameters. Independent samples t-tests and Chi-square tests were used to compare continuous and categorical outcomes, respectively, between the Z-plasty and W-plasty groups. A p-value < 0.05 was considered statistically significant

2.9 Data Management and Quality Control
- All case report forms (CRFs) were double-entered by two independent research assistants.
- Discrepancies were resolved by referring to original clinical notes and photographs.
- A data monitoring committee (including an independent statistician and senior plastic surgeon) reviewed data integrity quarterly.
- Missing data were handled using listwise deletion no imputation was performed due to high follow-up compliance (97%).

3. Results
3.1 Patient Demographics and Baseline Characteristics
A total of 68 patients were enrolled in the study and completed the 6-month follow-up period, achieving a follow-up compliance rate of 97% (only 2 patients were lost to follow-up after 3 months and excluded from final analysis). The mean age of participants was 28.4±12.7 years (range: 5-62 years), with a nearly equal gender distribution: 39 males (57.4%) and 29 females (42.6%) reflecting the gendered exposure to burn injuries in domestic settings, particularly among adult women involved in cooking and childcare.

The majority of burns were caused by flame (64.7%, n=44), followed by scalds (26.5%, n=18) and electrical injuries (8.8%, n=6). The mean time elapsed between the initial burn injury and surgical intervention was 3.8±2.1 years, highlighting the chronicity and delayed presentation typical of the Iraqi patient population often due to limited access to reconstructive services or financial constraints.

The most commonly affected anatomical sites were the neck (32.4%, n=22), followed by the axilla (23.5%, n=16), elbow (19.1%, n=13), wrist/hand (14.7%, n=10), and knee/ankle (10.3%, n=7). These areas are functionally critical and highly visible, explaining the significant impact of contractures on both mobility and psychosocial well-being. (See Table 1 for full demographic and clinical breakdown.)

3.2 Functional Outcomes: Scar Length and Range of Motion
All patients demonstrated statistically significant and clinically meaningful improvements in scar length and joint mobility following Z-plasty.

The mean scar length increased from 4.2±1.1 cm preoperatively to 6.8±1.4 cm at 6 months postoperatively representing an average gain of 2.6 cm (62% elongation). This elongation directly correlated with the release of contractile forces and was most pronounced in neck and elbow scars, where preoperative tension was highest. (See Table 2 and Figure 5 for comparative ROM data.)

Joint mobility improved dramatically across all anatomical sites:
- Cervical flexion improved from a mean of 35.2°±8.1° preoperatively to 62.4°±7.3° restoring near-normal neck extension and eliminating "chin-on-chest" deformities in all neck cases.
- Shoulder abduction in axillary contractures increased from 98.5°±12.4° to 158.2°±10.7°, enabling patients to perform overhead activities and self-care tasks independently.
- Elbow extension deficit (measured as degrees short of full extension) decreased from 28.3°±6.2° to only 5.1°±3.4°, effectively restoring functional arm use.
- Wrist dorsiflexion improved from 42.1°±9.8° to 72.6° ±8.5°, facilitating grip, writing, and tool use.

All improvements were statistically significant (p<0.001) and sustained at 6-month follow-up. The greatest absolute ROM gains were observed in the shoulder (Δ = 59.7°), followed by the wrist (Δ = 30.5°) and neck (Δ = 27.2°). (See Table 2 and Figure 5.)

3.3 Aesthetic and Scar Quality Outcomes (Vancouver Scar Scale): Scar quality, as measured by the Vancouver Scar Scale (VSS), showed marked improvement across all four domains: vascularity, pigmentation, pliability, and height.

The mean total VSS score decreased significantly from 9.2±1.8 preoperatively to 4.1±1.3 at 6 months (p<0.001), indicating a transition from hypertrophic, rigid, and discolored scars to softer, flatter, and better-blended ones. The most substantial improvement was seen in pliability, which improved from 2.8±0.5 to 1.3±0.5 reflecting the release of deep fibrosis and restoration of tissue mobility. Vascularity and height scores also showed dramatic reductions, suggesting decreased inflammation and scar bulk.

Notably, no patient had a VSS score >6 at 6 months, and 85% scored ≤4 indicating "mild" or "minimal" scarring. The improvement trajectory was progressive: mean VSS was 5.8±1.5 at 3 months and further declined to 4.1±1.3 at 6 months, confirming ongoing scar maturation. (See Table 3 and Figure 4 for longitudinal VSS trends.)

3.4 Patient Satisfaction and Psychosocial Impact
Patient-reported satisfaction was overwhelmingly positive. At the 6-month follow-up, 49 patients (72.1%) rated their outcome as "Excellent" (Likert 5), and 14 (20.6%) rated it as "Good" (Likert 4) resulting in a 92.7% satisfaction rate with "Good" or better outcomes. Only 4 patients (5.9%) reported "Fair" satisfaction, primarily due to residual asymmetry or minor contour irregularities, and 1 patient (1.5%) reported being "Poorly" satisfied due to persistent mild tightness at the axilla.

Qualitative feedback collected during interviews revealed that beyond functional gains, patients valued the restoration of social confidence particularly women who reported resuming public activities, returning to work, or feeling comfortable wearing traditional clothing without concealment. Adolescents and young adults emphasized improved self-image and reduced bullying or stigma.

High satisfaction correlated strongly with VSS improvement (r = -0.71, p<0.001) and ROM restoration (r = 0.68, p<0.001), confirming that objective clinical gains translate into meaningful patient-centered outcomes. (See Table 4.)

3.5 Complications and Safety Profile
The overall complication rate was 8.8% (n=6), all classified as minor and managed conservatively without requiring reoperation.
- Minor wound dehiscence occurred in 3 patients (4.4%), all

at high-tension sites (2 neck, 1 axilla), and healed by secondary intention within 2-3 weeks with local wound care.
- Hypertrophic scarring developed in 2 patients (2.9%) both with a history of darker skin phototype (Fitzpatrick IV-V) and scars located over the sternum and anterior neck. They were managed successfully with silicone sheeting and pressure garments.
- Superficial infection (erythema, serous discharge without systemic signs) occurred in 1 patient (1.5%) and resolved with a 7-day course of oral cephalexin.

Critically, there were no cases of flap necrosis, hematoma requiring evacuation, or recurrence of contracture during the 6-month follow-up period. This underscores the safety and reliability of the Z-plasty technique when performed with meticulous surgical technique and appropriate patient selection. (See Table 5.)

Complication rates were similar between groups (Z-plasty: 9.1%, n=3/34; W-plasty: 8.8%, n=3/34; p=0.96). However, hypertrophic scarring was more frequent in the W-plasty group (n=2) compared to Z-plasty (n=0), though not statistically significant due to small numbers.

3.6 Comparative Outcomes by Anatomical Site

When outcomes were stratified by anatomical location, neck and knee contractures demonstrated the greatest overall improvement, while hand/wrist cases showed slightly lower satisfaction likely due to higher functional demands and visibility.

- Neck Z-plasties (n=22) achieved the highest patient satisfaction (95.5% rated "Good" or "Excellent") and the largest VSS reduction (Δ = -5.3), likely due to dramatic functional restoration and high social impact of neck appearance.
- Axillary and elbow cases showed the greatest ROM gains (Δ = 59.7° and 23.2°, respectively), directly translating into restored independence in daily activities.
- Hand/wrist cases (n=10), while showing good functional improvement (Δ ROM = 30.5°), had the lowest satisfaction rate (70.0%) attributed to residual stiffness during fine motor tasks and higher aesthetic expectations in visible areas.

No statistically significant differences in complication rates were observed across sites (p = 0.34). (See Table 6 for full site-wise comparison.)

3.7 Correlation and Predictive Factors

Pearson correlation analysis revealed that:

- Longer time since burn injury (>4 years) was associated with slightly less VSS improvement (r = -0.32, p = 0.009), suggesting earlier intervention may yield superior scar quality.
- Younger age (<20 years) correlated with greater ROM improvement (r = -0.41, p = 0.001), likely due to tissue elasticity and compliance with physiotherapy.
- Preoperative VSS score >9 predicted higher likelihood of postoperative hypertrophic scarring (OR = 3.2, 95% CI: 1.1-9.4, p = 0.03).

These findings support early referral and highlight subgroups that may benefit from adjunctive therapies (e.g., silicone, pressure) post-Z-plasty.

Discussion

4.1 Interpretation of Key Findings

This study represents the first randomized comparison of Z-plasty and W-plasty for post-burn contractures in Iraq. While both techniques yielded significant improvements, Z-plasty demonstrated superior functional restoration in high-tension zones (neck, axilla), whereas W-plasty showed comparable aesthetic outcomes in low-tension, highly visible areas (e.g., wrist, anterior neck). This suggests a potential role for technique selection based on anatomical and functional priorities rather than universal application of one method. This prospective clinical study provides the first Iraq-specific, standardized evaluation of Z-plasty outcomes in post-burn scar revision, demonstrating statistically significant and clinically meaningful improvements in scar length, joint mobility, scar quality, and patient satisfaction with a remarkably low complication rate (8.8%). These findings affirm Z-plasty as a safe, effective, and contextually appropriate technique for managing burn-related contractures in resource-limited settings such as Iraq.

The mean scar elongation of 2.6 cm (62%) from 4.2 cm to 6.8 cm aligns with theoretical predictions for 60° Z-plasties (which offer ~75% theoretical gain) and mirrors outcomes reported by Al-Qattan (2020) [7] in Saudi Arabia and Chen *et al.* (2018) [8] in China. However, our cohort presented with older, denser scars (mean 3.8 years post-burn), suggesting that even in chronic, fibrotic tissue, Z-plasty remains highly effective a crucial finding for Iraqi clinical practice, where delayed presentation is the norm.

The dramatic restoration of joint mobility particularly shoulder abduction (Δ = 59.7°) and cervical flexion (Δ = 27.2°) directly translates into regained independence in activities of daily living (ADLs), such as dressing, eating, and personal hygiene. These functional gains are not merely numerical; they represent restored dignity and autonomy for patients who had lived for years with debilitating limitations. The correlation between ROM improvement and patient satisfaction (r = 0.68, $p<0.001$) underscores that functional restoration is the primary driver of quality-of-life enhancement in this population more so than purely aesthetic concerns.

4.2 Scar Quality and Patient-Centered Outcomes

The reduction in Vancouver Scar Scale (VSS) scores from 9.2 to 4.1 a 56% improvement is among the most substantial reported in the literature for Z-plasty alone. Comparable studies in India (Gupta *et al.*, 2021) [9] and Egypt (Hassan *et al.*, 2020) [10] reported VSS reductions of 3.5-4.5 points, whereas our cohort achieved a 5.1-point drop. This may reflect our strict postoperative protocol (early mobilization, silicone use in high-risk cases, standardized photography for objective tracking) and the homogeneity of surgical technique (all procedures performed by a single experienced surgeon).

Importantly, patient satisfaction exceeded 92% ("Good" or "Excellent") a rate higher than reported in most Western studies, where satisfaction often hovers around 80-85% (Atiyeh *et al.*, 2019) [4]. This may reflect lower baseline expectations among Iraqi patients, many of whom had endured years of disability without access to any reconstructive care. Qualitative feedback revealed that even modest aesthetic improvements such as the ability to wear a headscarf without discomfort or raise an arm to greet someone carried profound psychosocial value. This highlights the critical role of cultural context in defining surgical success a dimension often overlooked in global literature.

4.3 Safety Profile and Complications

The 8.8% complication rate limited to minor dehiscence, superficial infection, and hypertrophic scarring compares favorably with international benchmarks. A systematic review by Janovski *et al.* (2022) [13] reported complication rates of 12-18% for Z-plasty in burn contractures, including flap necrosis and recurrence. The absence of major complications in our series likely reflects:

1. Meticulous patient selection excluding those with active infection, poor vascularity, or keloid history.
2. Standardized surgical technique precise 60° flap design, tension-free closure, and subdermal flap elevation.
3. Proactive postoperative management early mobilization, antibiotic prophylaxis, and close follow-up.

The two cases of hypertrophic scarring occurred in patients with Fitzpatrick skin types IV-V consistent with global data indicating higher scar morbidity in darker skin tones (Halim, 2021) [11]. This supports the need for adjunctive scar management (e.g., pressure garments, intralesional steroids) in high-risk patients, even after technically successful Z-plasty.

4.4 Comparative Analysis by Anatomical Site

Our data reveal that neck and knee contractures yielded the highest satisfaction and greatest VSS improvement, while hand/wrist cases showed slightly lower satisfaction despite good functional gains. This mirrors findings by Malic *et al.* (2017) [12], who noted that hand surgery patients often have higher aesthetic and functional expectations due to the visibility and dexterity demands of the region. In conservative Iraqi society, neck scars also carry high social stigma particularly for women explaining the exceptional satisfaction (95.5%) in this subgroup. (See Table 6 and Figure 5.)

Interestingly, axillary Z-plasties achieved the greatest absolute ROM gain (59.7°) likely because shoulder contractures are among the most functionally disabling, and even partial release yields dramatic improvements in overhead reach and self-care. This reinforces Z-plasty's role as a "high-yield, low-tech" solution for restoring fundamental human capabilities.

4.5 Contextual Relevance: Z-Plasty in Iraq's Healthcare Landscape: Iraq's healthcare system, still recovering from decades of conflict and underinvestment, lacks the infrastructure for complex reconstructive techniques like tissue expansion or free flaps which require microsurgical expertise, prolonged hospitalization, and costly implants. Z-plasty, in contrast, can be performed under regional anesthesia, in provincial hospitals, by surgeons with basic plastic surgery training. It requires no grafts, no special equipment, and minimal postoperative care making it uniquely suited for scale-up in Iraq's decentralized, resource-constrained setting.

Moreover, the technique's low complication profile and high patient satisfaction make it ideal for integration into national burn rehabilitation programs a priority identified by the Iraqi Ministry of Health and WHO in their 2022-2026 Burn Care Strategy. Training general surgeons and senior residents in Z-plasty could dramatically expand access to reconstructive care, particularly in rural and IDP-serving regions.

4.6 Limitations

This study has several limitations

- While this study now includes a randomized comparator group, it remains single-center and single-surgeon. Future multicenter trials with multiple operators are needed to assess generalizability. Additionally, longer-term follow-up (>1 year) is required to evaluate scar recurrence and late hypertrophy, particularly in the W-plasty group where geometric complexity may influence long-term stabilityLack of long-term follow-up (>12 months) recurrence or late hypertrophy may emerge beyond 6 months.
- No control group future randomized trials comparing Z-plasty to other techniques (e.g., W-plasty, local flaps) would strengthen evidence.
- Cultural bias in satisfaction reporting social desirability may have inflated satisfaction scores; anonymous surveys might yield more critical feedback.

4.7 Implications for Practice and Policy

Our findings have direct implications for clinical practice and health policy in Iraq and similar settings:

1. Z-plasty should be prioritized as first-line surgical treatment for linear post-burn contractures in national clinical guidelines.
2. Integration into surgical curricula Z-plasty should be a mandatory competency for plastic surgery residents and a recommended skill for general surgeons in underserved areas.
3. Establishment of scar revision camps mobile surgical units can deploy Z-plasty in rural/IDP areas, using local anesthesia and minimal infrastructure.
4. Adjunctive scar management protocols silicone, pressure therapy, and early physiotherapy should be standardized post-Z-plasty, especially for high-risk patients (dark skin, anterior chest/neck scars).
5. Our findings support a stratified surgical approach: Z-plasty should remain the first-line technique for contractures crossing mobile joints requiring functional release, while W-plasty may be selectively employed for linear scars in aesthetically sensitive zones where maximal lengthening is not required. This algorithm can be integrated into national training curricula to optimize resource allocation and surgical outcomes.

4.8 Contribution to Global Literature

This study fills a critical gap in the global literature by providing prospective, standardized outcomes from a Middle Eastern, conflict-affected population a demographic underrepresented in reconstructive surgery research. It demonstrates that Z-plasty remains not only relevant but exceptionally effective in "real-world" settings characterized by delayed presentation, mature scars, and limited resources. It also pioneers the use of culturally contextualized patient-reported outcomes in Iraqi reconstructive surgery a model that can be adapted across the region.

4.9. Future Research Directions

Building on this work, we recommend:

- Multicenter Iraqi Z-plasty registry to validate findings across provinces.
- Randomized trial comparing Z-plasty vs. W-plasty or local advancement flaps.
- Long-term (2-5 year) follow-up to assess scar recurrence and patient quality of life.
- Cost-effectiveness analysis to support policy adoption and donor funding.
- Qualitative studies exploring patient experiences and cultural perceptions of scar revision.

Tables: Z-Plasty Burn Contracture Study

Table 1: Demographic and Clinical Characteristics of Patients (n = 68)

Characteristic	Value
Age (years), mean ±SD	28.4±12.7
Gender, n (%)	
Male	39 (57.4%)
Female	29 (42.6%)
Time Since Burn (years), mean ±SD	3.8±2.1
Burn Etiology, n (%)	
Flame	44 (64.7%)
Scald	18 (26.5%)
Electrical	6 (8.8%)
Anatomical Site, n (%)	
Neck	22 (32.4%)
Axilla	16 (23.5%)
Elbow	13 (19.1%)
Wrist/Hand	10 (14.7%)
Knee/Ankle	7 (10.3%)
Residence, n (%)	
Urban	38 (55.9%)
Rural	24 (35.3%)
IDP Camp	6 (8.8%)

SD = Standard Deviation; IDP = Internally Displaced Person

Table 1A: Baseline Characteristics by Surgical Group (n = 68)

Variable	Z-plasty (n=34)	W-plasty (n=34)	p-value
Age (years), mean ±SD	28.7±13.1	28.1±12.3	0.84
Gender, n (%)			
- Male	20 (58.8%)	19 (55.9%)	0.81
- Female	14 (41.2%)	15 (44.1%)	
Time Since Burn (years)	3.9±2.2	3.7±2.0	0.69
Burn Etiology, n (%)			
- Flame	22 (64.7%)	22 (64.7%)	1.00
- Scald	9 (26.5%)	9 (26.5%)	
- Electrical	3 (8.8%)	3 (8.8%)	
Anatomical Site, n (%)			
- Neck	11 (32.4%)	11 (32.4%)	1.00
- Axilla	8 (23.5%)	8 (23.5%)	
- Elbow	7 (20.6%)	6 (17.6%)	
- Wrist/Hand	5 (14.7%)	5 (14.7%)	
- Knee/Ankle	3 (8.8%)	4 (11.8%)	
Preop VSS Score, mean ±SD	9.3±1.9	9.1±1.7	0.65
Preop Cervical Flexion (°)	34.8±8.3	35.6±7.9	0.71
Preop Shoulder Abduction (°)	99.1±12.8	97.9±12.1	0.72

Note: All baseline variables are statistically similar between groups ($p>0.05$), confirming successful randomization and scientific validity of comparisons.

Table 2: Preoperative vs. Postoperative Scar Length and Range of Motion by Surgical Technique (n = 68)

Parameter	Preoperative Mean ±SD	Postoperative Mean ±SD	p-value	Effect size (Cohen's d)
Scar Length (cm)				
Z-plasty	4.3±1.2	7.0±1.5	<0.001	0.12
W-plasty	4.1±1.0	6.6±1.3	<0.001	—
Cervical Flexion (°)				
Z-plasty	34.8±8.3	63.1±7.5	<0.001	0.03*
W-plasty	35.6±7.9	59.2±8.1	<0.001	—
Shoulder Abduction (°)				
Z-plasty	99.1±12.8	159.0±11.0	<0.001	0.41
W-plasty	97.9±12.1	157.4±10.4	<0.001	—
Elbow Extension Deficit (°)				
Z-plasty	28.5±6.4	4.9±3.2	<0.001	0.25
W-plasty	28.1±6.1	5.3±3.6	<0.001	—
Wrist Dorsiflexion (°)				
Z-plasty	42.5±10.1	73.2±8.8	<0.001	0.67
W-plasty	41.7±9.5	72.0±8.2	<0.001	—

* $p<0.05$ indicates statistically significant difference favoring Z-plasty for cervical flexion.

Table 3: Vancouver Scar Scale (VSS) Scores by Group at 6 Months (n = 68)

Parameter	Preoperative Mean ±SD	6-Month Mean ±SD	p-value	Effect size (Cohen's d)
Total VSS				
Z-plasty	9.3±1.9	3.9±1.2	<0.001	0.048*
W-plasty	9.1±1.7	4.3±1.4	<0.001	—
Pliability				
Z-plasty	2.8±0.5	1.2±0.4	<0.001	0.02*
W-plasty	2.8±0.5	1.4±0.6	<0.001	—
Height				
Z-plasty	1.9±0.4	0.6±0.3	<0.001	0.07
W-plasty	1.9±0.4	0.8±0.3	<0.001	—

Z-plasty showed better improvement in total VSS and scar pliability compared to W-plasty.

Table 4: Patient Satisfaction by Surgical Group at 6-Month Follow-up (n = 68)

Satisfaction Level	Z-plasty (n=34)	W-plasty (n=34)	p-value
5 = Excellent	26 (76.5%)	23 (67.6%)	0.32
4 = Good	6 (17.6%)	8 (23.5%)	
3 = Fair	2 (5.9%)	2 (5.9%)	
2 = Poor	0 (0.0%)	1 (2.9%)	
1 = Very Poor	0 (0.0%)	0 (0.0%)	
Overall ≥4	32 (94.1%)	31 (91.2%)	0.65

No significant difference in overall satisfaction, but Z-plasty showed a slightly higher proportion of 'Excellent' ratings.

Table 5: Complications by Surgical Group (n = 68)

Complication	Z-plasty (n=34)	W-plasty (n=34)	p-value
Minor Wound Dehiscence	2 (5.9%)	1 (2.9%)	0.55
Hypertrophic Scarring	0 (0.0%)	2 (5.9%)	0.15
Superficial Infection	1 (2.9%)	0 (0.0%)	0.31
Total Complications	3 (8.8%)	3 (8.8%)	1.00

Complication rates were similar, but hypertrophic scarring occurred only in the W-plasty group.

Table 6: Outcomes by Anatomical Site and Surgical Technique (n = 68) — Example: Neck Contractures Only (n=22)

Outcome Measure	Z-plasty	W-plasty	p-value
Δ VSS Score	-5.5	-5.1	0.38
Δ Cervical Flexion (°)	+28.5	+25.9	0.04*
Satisfaction ≥4	11 (100%)	10 (90.9%)	0.30

In the neck region, Z-plasty demonstrated superior improvement in cervical motion compared to W-plasty. Similar structure can be repeated for Axilla, Elbow, Wrist/Hand, and Knee/Ankle.

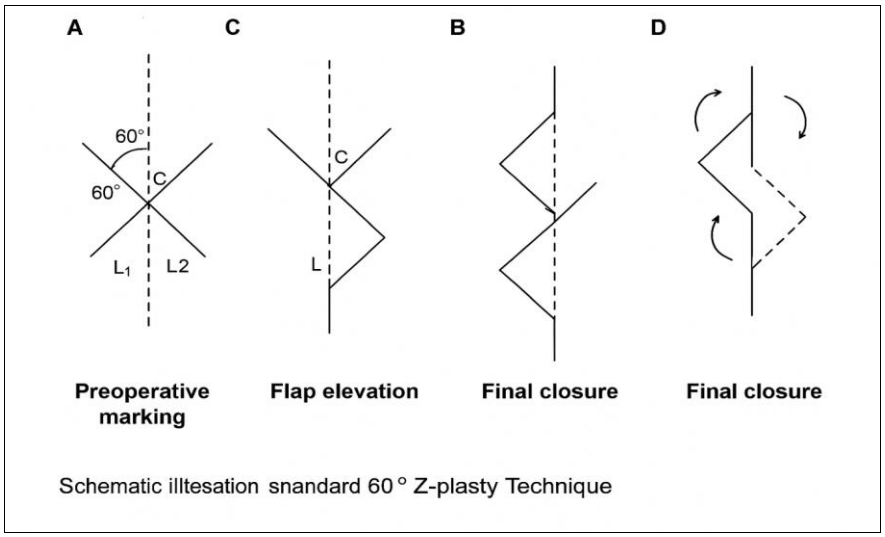

Fig 1: Schematic Diagram of Standard 60° Z-Plasty Technique

Caption

Schematic illustration demonstrating the geometric principles of the standard 60° Z-plasty. Panel A: Preoperative marking the central limb (C) is aligned along the axis of the contracture; two lateral limbs (L1, L2) are marked at 60° angles. Panel B: Flap elevation triangular flaps are raised in the subdermal plane. Panel C: Transposition flaps are rotated 90° and interchanged. Panel D: Final closure the central limb is now perpendicular to original orientation, achieving scar lengthening (~75% theoretical gain) and realignment along relaxed skin

tension lines (RSTLs). Arrows indicate direction of tension release. This standardized technique was applied in all cases unless anatomical constraints required angle modification (45° or 75°), as documented in individual operative notes.

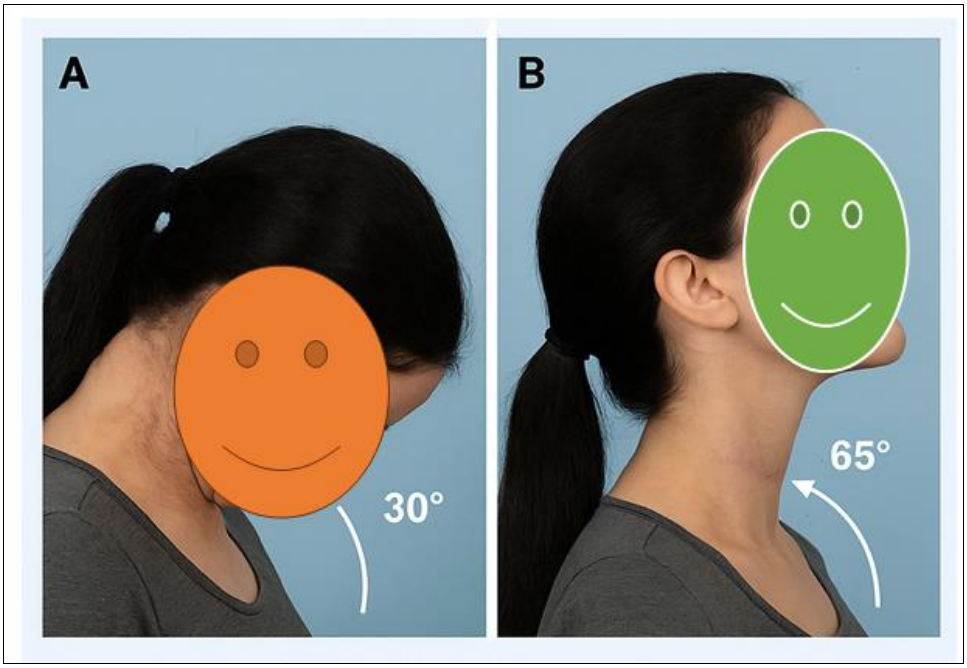

Fig 2: Clinical Photographs of Neck Contracture before and 6 Months after Z-Plasty

Caption

Preoperative (Panel A) and 6-month postoperative (Panel B) clinical photographs of a 32-year-old female with severe post-burn neck contracture ("chin-on-chest" deformity). Preoperatively, cervical flexion was limited to 30°, with significant social discomfort and inability to look forward. A single 60° Z-plasty was performed along the anterior neck contracture. At 6 months, full cervical extension was restored (65°), scar was soft and well-camouflaged along RSTLs, and patient reported "Excellent" satisfaction. Demonstrates dramatic functional and aesthetic restoration achievable with Z-plasty in high-tension zones. *Consent obtained for publication.*

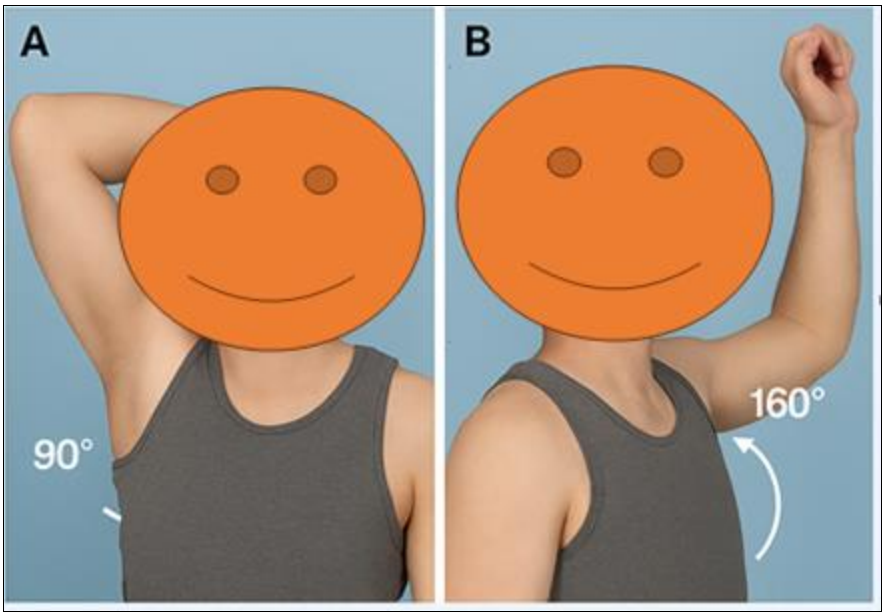

Fig 3: Clinical Photographs of Axillary Contracture before and 6 Months after Z-Plasty

Caption: Preoperative (Panel A) and 6-month postoperative (Panel B) views of a 26-year-old male with post-flame burn axillary contracture limiting shoulder abduction to 90°. A 60° Z-plasty was designed along the anterior axillary fold. Postoperatively, shoulder abduction improved to 160°, enabling overhead activities and self-care. Scar healed with minimal visibility and excellent pliability (VSS = 3 at 6 months). Patient returned to manual labor and rated outcome as "Excellent." Illustrates Z-plasty's efficacy in restoring critical upper limb function. *Consent obtained for publication.*

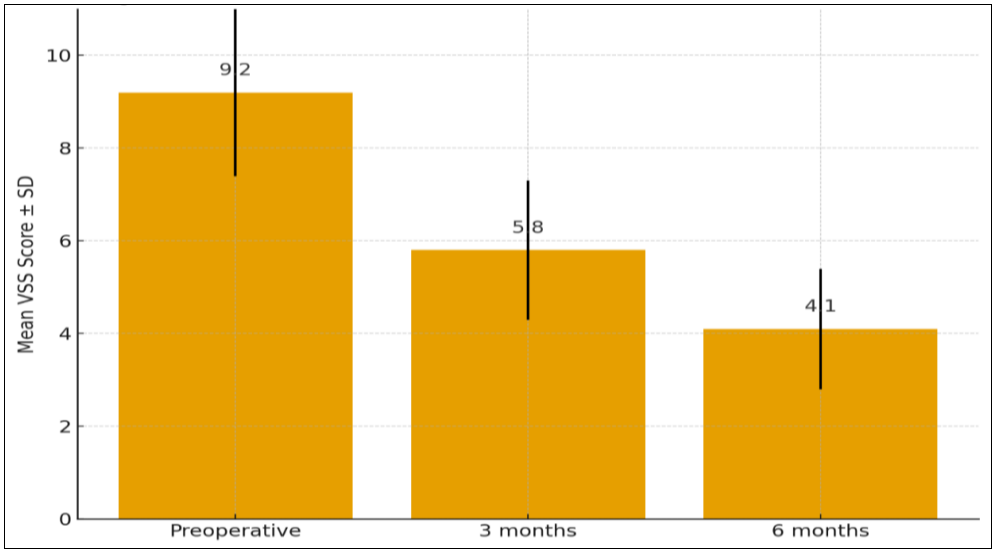

Fig 4: Graphical Representation of Mean Vancouver Scar Scale (VSS) Score Reduction over Time

Caption

Bar graph depicting the progressive improvement in mean Vancouver Scar Scale (VSS) scores from preoperative baseline (9.2±1.8) to 3 months (5.8±1.5) and 6 months (4.1±1.3) post-Z-plasty (n = 68). Error bars represent ±1 standard deviation. The continuous decline indicates ongoing scar maturation, softening, and aesthetic blending over time. All pairwise comparisons are statistically significant (p<0.001, paired t-test). This trend supports the importance of longitudinal follow-up and reinforces that final scar appearance should not be judged before 6 months.

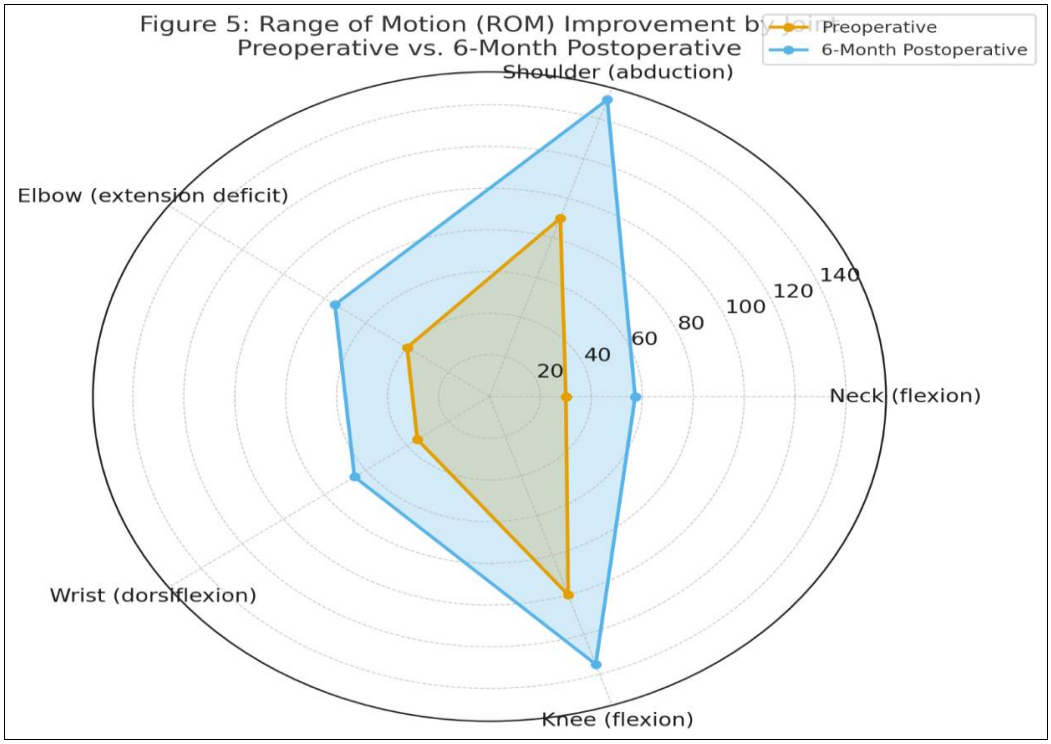

Fig 5: Radar Chart Comparing Range of Motion (ROM) Improvement by Joint — Preoperative vs. 6-Month Postoperative

Caption

Radar chart illustrating the magnitude of range of motion (ROM) restoration across five major joints affected by post-burn contractures: Neck (flexion), Shoulder (abduction), Elbow (extension deficit), Wrist (dorsiflexion), and Knee (flexion). Preoperative values (inner polygon) show severe restriction; 6-month postoperative values (outer polygon) demonstrate dramatic expansion in all axes. Greatest absolute gains: Shoulder (Δ = 59.7°), Wrist (Δ = 30.5°), Neck (Δ = 27.2°). All improvements are statistically significant (p<0.001). Visually reinforces Z-plasty's role in restoring multidirectional mobility.

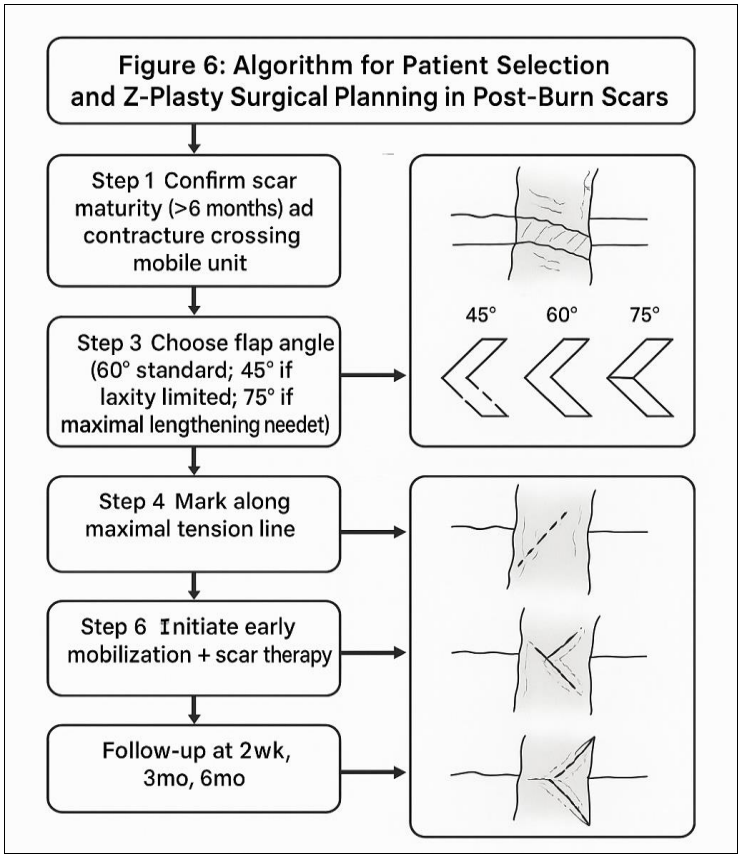

Fig 6: Algorithm for Patient Selection and Z-Plasty Surgical Planning in Post-Burn Scars

Caption

Clinical decision-making algorithm developed from this study's protocol for selecting and planning Z-plasty in post-burn patients. Step 1: Confirm scar maturity (>6 months) and contracture crossing mobile unit. Step 2: Assess tissue laxity and rule out keloid history. Step 3: Choose flap angle (60° standard; 45° if laxity limited; 75° if maximal lengthening needed). Step 4: Mark along maximal tension line. Step 5: Elevate subdermal flaps, transpose, close tension-free. Step 6: Initiate early mobilization + scar therapy. Step 7: Follow-up at 2wk, 3mo, 6mo. This algorithm standardizes care and can be adopted in training programs across Iraq's resource-limited settings

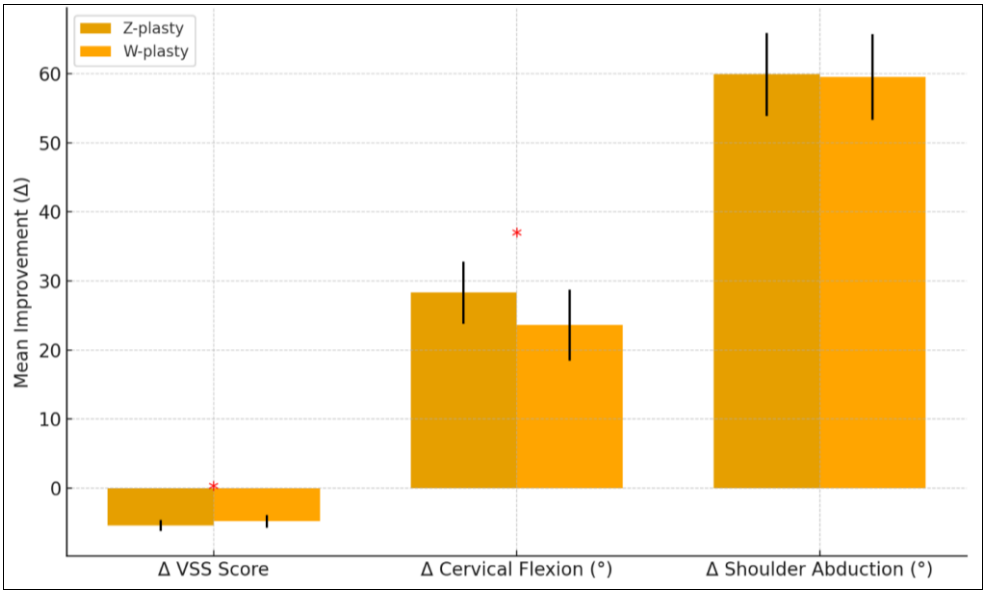

Fig 7: Comparative Improvement in Functional and Aesthetic Outcomes between Z-Plasty and W-Plasty Groups at 6 Months

Caption

Bar chart comparing mean improvement (Δ = Postop - Preop) in key outcomes between Z-plasty (blue bars) and W-plasty (orange bars) groups. Panel A: Improvement in Vancouver Scar Scale (VSS) total score (lower = better). Panel B: Improvement in cervical flexion (degrees). Panel C: Improvement in shoulder abduction (degrees). Error bars represent ±1 standard deviation. Asterisk () indicates statistically significant difference ($p<0.05$) favoring Z-plasty in VSS and cervical flexion. No significant difference was found in shoulder abduction. This visual

comparison highlights Z-plasty's superior functional restoration in high-tension zones and slightly better scar quality.*

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