# Formulaic Prediction of Z-Plasty Outcomes Relative to Z Scar Lengthening, Z Flap Tension, and Area of Distortion, and Determination of the Multiple Z-Plasty Configurations that Optimally Increase Z Scar Length, Decrease Z Flap Tension, and Decrease Area of Distortion

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## ABSTRACT

**Objective:** To generate mathematical formulas to predict Z-plasty outcomes relative to Z scar lengthening, Z flap tension, and area of distortion, and to determine the multiple Z-plasty configurations that optimally increase Z scar length, decrease Z flap tension, and decrease area of distortion.

**Methods:** Each Z-plasty configuration was evaluated for highest percent Z scar lengthening, lowest tension to close Z flap, and lowest area of distortion. For part 1 of the study, conventional one-flap, two-flap, four-flap, and eight-flap Z-plasties were created, after which relocation of the Z flaps was performed. The outcomes were analyzed and formulas were generated to predict Z-plasty outcomes. In part 2, the following modifications to the four-flap Z-plasty were made: modification of Z flap angle, modification of Z flap limb size, and addition of a gap between each Z flap. Outcomes were evaluated to identify the configuration that produced the optimal outcome for each outcome measure.

**Results:** Thirty-six pig skins were incised and sutured under controlled condition. For part 1, one-flap Z-plasty was best for Z scar lengthening, and 8-flap Z-plasty was best for reducing both tension to close and area of distortion. Three formulas were generated to predict the studied outcomes of Z-plasty. For part 2, the configuration that added a gap of 75% of the central limb length yielded the best outcome for scar length and also work very well for reducing the tension to close. The conventional design was the best for minimizing area of distortion.

**Conclusion:** Mathematical formulas were generated to predict Z scar percent lengthening, Z flap tension to close, and area of distortion. Addition of a gap 75% of the central limb length was the most efficacious Z-plasty configuration for increasing Z scar length.

**Keywords:** Mathematical prediction; Z-plasty outcomes; Z scar lengthening; Z flap tension; area of distortion; multiple Z-plasty configurations (Siriraj Med J 2019; 71: 506-514)

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## INTRODUCTION

Z-plasty is a valuable technique for plastic surgeons. Z-plasty is an effective surgical treatment to manage scar contracture[2,3,5,6], and it is incorporated in many plastic surgery procedures. The four fundamental functions of Z-plasty are: 1) To lengthen a scar or release a contracture; 2) To realign a scar within relaxed skin tension lines (RSTLs); 3) To move tissue from one area to another; and, 4) To obliterate or create a web or cleft.[7] Modifications of Z-plasty were developed to serve different purposes[8], and one of the most popular variations is multiple Z-plasty or compound Z-plasty technique. Multiple Z-plasty is defined as the linkage of two or more Z flaps. Multiple Z-plasty is an effective alternative for the management of large scars that would not respond well to the use of a single (one-flap) Z-plasty, because the large flaps of a single Z flap would effectuate more distortion and tension to the adjacent area than multiple smaller Z flaps. Many studies were conducted to understand and predict the effect of Z-plasty on adjacent tissue in both animal models1 and computer simulations.[4,9,10] However, methods to predict the surgical outcomes of Z-plasty, and data relating to the Z-plasty configurations that yield the best surgical outcomes are scarce. Accordingly, the aims of this study were to generate mathematical formulas to predict Z-plasty outcomes relative to Z scar lengthening, Z flap tension, and area of distortion, and to determine the multiple Z-plasty configurations that optimally increase Z scar length, decrease Z flap tension, and decrease area of distortion.

## MATERIALS AND METHODS

Fresh pig skins, including the epidermis, dermis, and subcutaneous layer were prepared. All specimens were cut to 16.0 x 16.0 cm in size, and to between 1.3 to 1.5 cm in thickness. Specimen temperature was maintained within the range of 25-30 degrees Celsius using an infrared thermometer. Skin surface tension was set within 0.07-0.08 newton/m (N/m)[12] by using digital manometer before commencement of the experiment.

Specimens were marked with colored dots located 0.5 cm apart, after which Z-plasty and multiple Z-plasty flaps were drawn then marked the reference point of both end of Z flap as point A and point B (After Z flap was relocated these points will be point A' and point B' respectively). After that incisions were made.

### Part 1

The conventional design of 1-flap, 2-flap, 4-flap, and 8-flap Z-plasties was performed, which consisted of 60 degree angle size and equality among all Z flap limb lengths (Fig 1A-D).

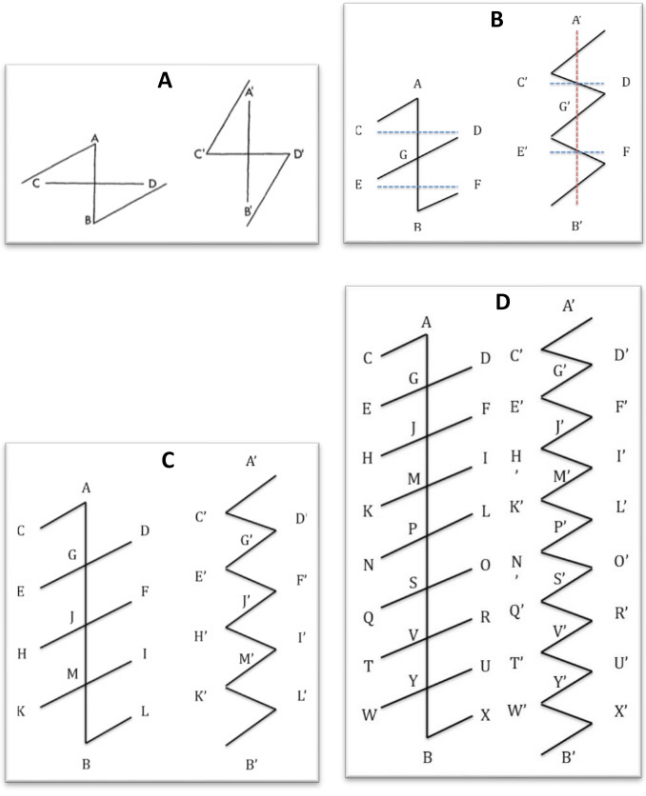



**Fig 1.** (A) One-flap Z-plasty, (B) Two-flap Z-plasty, (C) Four-flap Z-plasty, (D) Eight-flap Z-plasty.

### Part 2

Modifications to the conventional 4-flap Z-plasty were designed. First, we modified the angle of each Z flap to 75 and 45 degrees (Fig 2A), and to 90 and 30 degrees (Fig 2B). Second, we modified the size of Z flap limb length to 2.5 cm and 1.5 cm (Fig 2C), and also to alternating unequal Z flap peripheral limb size of 2.5 cm and 1.5 cm, and central limb size 2.0 cm (Fig 2D). Third, we added a gap between each Z flap, as follows:

1. Gap 0.5 cm (25% of central limb length; Fig 2E)
2. Gap 1.0 cm (50% of central limb length; Fig 2F)
3. Gap 1.5 cm (75% of central limb length; Fig 2G)
4. Gap 2.0 cm (100% of central limb length; Fig 2H)

Z flaps were then relocated to their final position and the following outcomes were measured: 1) actual scar length (centimeter, cm); tension to close (newton, N); and, area of distortion (square centimeter, cm2).

A descriptive analysis was performed, and the results are presented as mean, and as frequency and percentage for categorical variables. SPSS Statistics version 18 (SPSS, Inc., Chicago, IL, USA) was used to analyze the data.

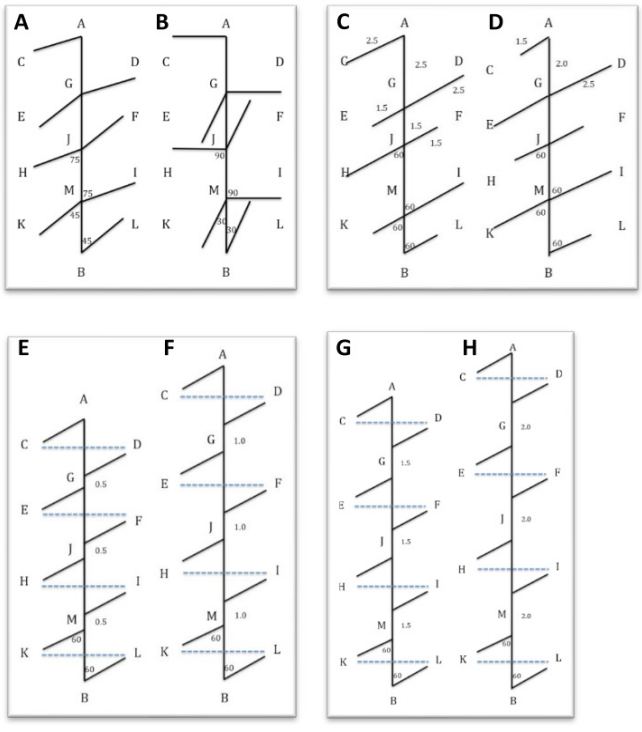



**Fig 2.** (A) Modification of the angles of each Z flap; 75 and 45 degrees, (B) Modification of the angles of each Z flap; 90 and 30 degrees, (C) Modification of the limb size of each Z flap; Z flap size 2.5 cm and 1.5 cm, (D) Unequal peripheral limb of Z flap size 2.5 cm, and 1.5 cm and central limb size 2.0 cm, (E) Addition of a gap between each Z flap; Gap of 0.5 cm (25% of limb size), (F) Addition of a gap between each Z flap; Gap of 1.0 cm (50% of limb size), (G) Addition of a gap between each Z flap; Gap of 1.5 cm (75% of limb size), (H) Addition of a gap between each Z flap; Gap of 2.0 cm (100% of limb size).

## RESULTS

### Part 1

This experimental study was performed on 36 pig skin specimens (12 designs, 3 per each design), and post-procedure measurements were taken and recorded.

For one-flap Z plasty, it increased the length about 46.875%, need tension to close the Z flap about 5.283 N, and create area of distortion about 208.0 $cm^2$. For two-flap Z plasty, it increased the length about 31.25%, need tension to close the Z flap about 5.913 N, and create area of distortion about 122.375 $cm^2$. For four-flap Z plasty, it increased the length about 18.75%, need tension to close the Z flap about 6.433 N, and create area of distortion about 84.5 $cm^2$. For eight-flap Z plasty, it increased the length about 17.5%, need tension to close the Z flap about 3.255 N, and create area of distortion about 37.5 $cm^2$.

The results of each design were compared (Table 1), and we found that 1-flap Z-plasty yielded the best result in terms of scar lengthening, followed by 2-flap, 4-flap, and 8-flap Z-plasty.

Regarding the tension needed to close the Z flap and the area of distortion, the authors found that 8-flap Z-plasty produced both the least tension and the least area of distortion after Z flap relocation, followed by 4-flap, 2-flap, and 1-flap Z-plasty.

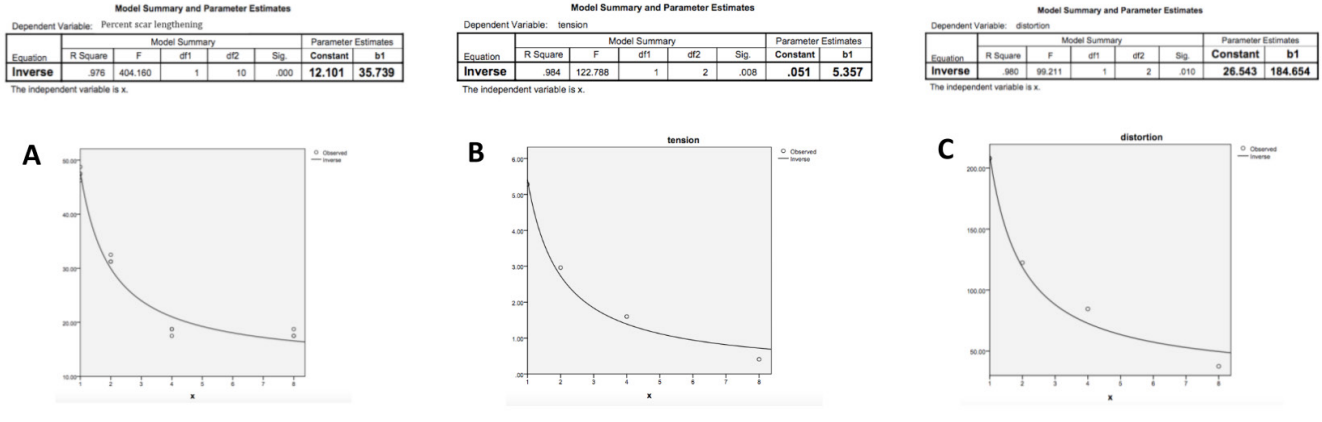
From the data we found, the curve estimation models were match with inverse equation; Y = b0 + (b1 / t), (Y = result from equation, b0 = constant, b1 = constant, t = number of Z plasty) (Fig 3A-C).[1]

Finally, the mathematical models that were generated to predict percent scar lengthening, tension to close Z flap, and area of distortion outcomes after Z-plasty are, as follows:

| | |
|---|---|
| Percent lengthening | = 12.10 + (35.74 / t) |
| Tension to close Z flap | = 0.05 + (5.36 / t) |
| Area of distortion | = 26.54 + (184.65 / t) |

### Part 2

In this part, the authors set forth to evaluate the effect of each modified Z-plasty technique. The studied



Model Summary and Parameter Estimates

Dependent Variable: Percent scar lengthening

| Equation | Model Summary | | | | | Parameter Estimates | |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Inverse | .976 | 404.160 | 1 | 10 | .000 | 12.101 | 35.739 |

The independent variable is x.

Model Summary and Parameter Estimates

Dependent Variable: tension

| Equation | Model Summary | | | | | Parameter Estimates | |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Inverse | .984 | 122.788 | 1 | 2 | .008 | .051 | 5.357 |

The independent variable is x.

Model Summary and Parameter Estimates

Dependent Variable: distortion

| Equation | Model Summary | | | | | Parameter Estimates | |
|---|---|---|---|---|---|---|---|
| | R Square | F | df1 | df2 | Sig. | Constant | b1 |
| Inverse | .980 | 99.211 | 1 | 2 | .010 | 26.543 | 184.654 |

The independent variable is x.



**Fig 3.** (A) Model summary of percent scar lengthening; percent scar lengthening: b0 (constant) = 12.10, b1 = 35.74, (B) Model summary of tension to close Z flap; tension to close Z flap: b0 (constant) = 0.05, b1 = 5.36, (C) Model summary of area of distortion; area of distortion: b0 (constant) = 26.54, b1 = 184.65.

**TABLE 1.** Measurement parameters compared among the 4 conventional Z-plasty designs.

| Type | Original length (cm) | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Total tension to close (N) | Area of distortion ($cm^2$) |
|---|---|---|---|---|---|---|
| **1-flap Z-plasty** | 8.0 | 11.8 | 3.8 | 46.875 | 5.283 | 208.0 |
| **2-flap Z-plasty** | 8.0 | 10.5 | 2.5 | 31.25 | 5.913 (2.957 each) | 122.375 |
| **4-flap Z-plasty** | 8.0 | 9.5 | 1.5 | 18.75 | 6.433 (1.608 each) | 84.5 |
| **8-flap Z-plasty** | 8.0 | 9.4 | 1.4 | 17.5 | 3.255 (0.407 each) | 37.5 |

modifications included modifying the angle of each Z flap (Fig 2A and 2B), modifying the limb size of Z flap (Fig 2C and 2D), and adding a gap between each Z flap (Fig 2E, 2F, 2G, and 2H). The results were then compared, including with the conventional 4-flap Z-plasty design (Fig 1C). The outcomes of each modification are shown in Tables 2 to 9 (Supplement data), with comparative data shown in Table 10.

In Table 2 and Table 3, modifying the angle of each Z flap yield the results that less effective than the conventional design in all 3 circumstances (Percent lengthening, Tension to close Z flap, and Area of distortion). In Table 4, modifying the limb size of Z flap from 2.5 cm to 1.5 cm yield the results that less effective than the conventional design in all 3 circumstances. For the modifying the limb size of Z flap to 2.0 cm for the central limb size, and 2.5 cm and 1.5 cm for the sizes of the peripheral limbs (Table 5) shown comparable result to the conventional one in term of percent lengthening, better in tension to close Z flap, but significantly worse in area of distortion. In Table 6 to Table 9, every design of adding a gap between each Z flap can significantly reduce the tension to close Z flap better than the conventional design. Especially for the design that adding a gap of 0.5 cm (25% of central limb length) that yield the best result. And for percent lengthening, adding a gap between each Z flap of 1.5 cm (75% of central limb length) shown very interest outcome, because it yielded the better result than the conventional design (21.60% vs 18.75%).

The results revealed that the addition of a gap of 1.5 cm (or 75% of central limb length) was the best design for lengthening the Z scar, followed by the conventional design and then the design that alternates the limb size of the Z flap from 2.5 cm to 1.5 cm. Regarding the lowering of tension, addition of a gap of 0.5 cm (or 25% of central limb length) yielded the best result, followed by addition of a gap of 1.5 cm (or 75% of central limb length). For area of distortion, the conventional technique yielded the best outcomes (Table 10).

## DISCUSSION

In part 1, the authors generated the following mathematical formulas to predict surgical outcomes after Z-plasty:

Percent scar lengthening = 12.10 + (35.74 / t)
Tension to close Z flap = 0.05 + (5.36 / t)
Area of distortion = 26.54 + (184.65 / t)

Compare to the previous studies[1,11], our new version of mathematical models are easier to use, to remember and can estimate the final outcomes of multiple Z plasty not only the percentage of scar lengthening but also the flap tension and area of distortion.

In part 2 of this study, the authors found that addition of a gap of 1.5 cm (or 75% of the central limb length) was the best design to optimally lengthen the Z scar (2.85% better than the conventional design (21.6% vs 18.75%)). This new knowledge will significantly help us to combat with the contracted scar. The design that added a gap of 0.5 cm (or 25% of the central limb length) yielded the best outcome relative to lowering the tension needed to close the Z flap. The conventional Z-plasty design was found to deliver the best outcome relative to area of distortion.

**TABLE 2.** Outcomes of modifying the angle of each Z flap from 75 degrees to 45 degrees.

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 8.0 | | | |
| A'B' (AB = 8.0) | 9.2 | 1.2 | 15.00 | |
| A'G' (AG = 2.0) | 2.2 | 0.2 | 10.00 | |
| G'J' (GJ = 2.0) | 2.2 | 0.2 | 10.00 | |
| J'M' (JM = 2.0) | 2.3 | 0.3 | 15.00 | |
| M'B' (MB = 2.0) | 2.5 | 0.5 | 25.00 | |
| **Actual length** | | | | |
| C'D" (CD = 3.80) | 1.9 | -1.9 | -50.00 | |
| E'F' (EF = 2.83) | 2.2 | -0.63 | -22.26 | |
| H'I' (HI = 3.80) | 2.1 | -1.7 | -44.74 | |
| K'L' (KL = 2.83) | 2.1 | -0.73 | -25.80 | |
| **Tension to close (N)** | | | | 10.086 |
| First Z-plasty | | | | 2.850 |
| Second Z-plasty | | | | 1.578 |
| Third Z-plasty | | | | 3.499 |
| Fourth Z-plasty | | | | 2.159 |
| **Area of distortion ($cm^2$)** | | | | 96.0 |

**TABLE 3.** Outcomes of modifying the angle of each Z flap from 90 degrees to 30 degrees.

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 8.0 | | | |
| A'B' (AB = 8.0) | 9.2 | 1.2 | 15.00 | |
| A'G' (AG = 2.0) | 2.4 | 0.4 | 20.00 | |
| G'J' (GJ = 2.0) | 2.1 | 0.1 | 5.00 | |
| J'M' (JM = 2.0) | 2.5 | 0.5 | 25.00 | |
| M'B' (MB = 2.0) | 2.2 | 0.2 | 10.00 | |
| **Actual length** | | | | |
| C'D" (CD = 4.0) | 2.3 | -1.7 | -42.50 | |
| E'F' (EF = 2.0) | 1.8 | -0.2 | -10.00 | |
| H'I' (HI = 4.0) | 2.4 | -1.6 | -40.00 | |
| K'L' (KL = 2.0) | 1.7 | -0.3 | -15.00 | |
| **Tension to close (N)** | | | | 15.726 |
| First Z-plasty | | | | 5.643 |
| Second Z-plasty | | | | 2.960 |
| Third Z-plasty | | | | 5.288 |
| Fourth Z-plasty | | | | 1.835 |
| **Area of distortion ($cm^2$)** | | | | 99.375 |

**TABLE 4.** Outcomes of modifying the limb size of the Z flap from 2.5 cm to 1.5 cm.

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 8.0 | | | |
| A'B' (AB = 8.0) | 9.4 | 1.4 | 17.50 | |
| A'G' (AG = 2.5) | 3.0 | 0.5 | 20.00 | |
| G'J' (GJ = 1.5) | 1.7 | 0.2 | 13.33 | |
| J'M' (JM = 2.5) | 2.9 | 0.4 | 16.00 | |
| M'B' (MB = 1.5) | 1.8 | 0.3 | 20.00 | |
| **Actual length** | | | | |
| C'D" (CD = 4.4) | 2.6 | -1.8 | -40.91 | |
| E'F' (EF = 2.6) | 1.8 | -0.8 | -30.77 | |
| H'I' (HI = 4.4) | 2.6 | -1.8 | -40.91 | |
| K'L' (KL = 2.6) | 1.8 | -0.8 | -30.77 | |
| **Tension to close (N)** | | | | 8.425 |
| First Z-plasty | | | | 1.481 |
| Second Z-plasty | | | | 1.877 |
| Third Z-plasty | | | | 3.022 |
| Fourth Z-plasty | | | | 2.045 |
| **Area of distortion ($cm^2$)** | | | | 95.25 |

**TABLE 5.** Outcomes of modifying the limb size of Z flap to 2.0 cm for the central limb size, and 2.5 cm and 1.5 cm for the sizes of the peripheral limbs.

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 8.0 | | | |
| A'B' (AB = 8.0) | 9.5 | 1.5 | 18.75 | |
| A'G' (AG = 2.0) | 2.3 | 0.3 | 15.00 | |
| G'J' (GJ = 2.0) | 2.3 | 0.3 | 15.00 | |
| J'M' (JM = 2.0) | 2.5 | 0.5 | 25.00 | |
| M'B' (MB = 2.0) | 2.4 | 0.4 | 20.00 | |
| **Actual length** | | | | |
| C'D" (CD = 3.5) | 2.4 | -1.1 | -31.43 | |
| E'F' (EF = 3.5) | 2.5 | -1.0 | -28.57 | |
| H'I' (HI = 3.5) | 2.6 | -0.9 | -25.71 | |
| K'L' (KL = 3.5) | 2.5 | -1.0 | -28.57 | |
| **Tension to close (N)** | | | | 5.620 |
| First Z-plasty | | | | 2.212 |
| Second Z-plasty | | | | 0.703 |
| Third Z-plasty | | | | 1.937 |
| Fourth Z-plasty | | | | 0.768 |
| **Area of distortion ($cm^2$)** | | | | 120.25 |

**TABLE 6.** Outcomes of adding a gap between each Z flap of 0.5 cm (25% of central limb length).

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 9.5 | | | |
| A'B' (AB = 9.5) | 10.9 | 1.4 | 14.74 | |
| A'G' (AG = 2.25) | 2.6 | 0.35 | 15.56 | |
| G'J' (GJ = 2.5) | 2.8 | 0.3 | 12.00 | |
| J'M' (JM = 2.5) | 2.8 | 0.3 | 12.00 | |
| M'B' (MB = 2.25) | 2.7 | 0.45 | 20.00 | |
| **Actual length** | | | | |
| C'D" (CD = 3.46) | 2.3 | -1.16 | -33.53 | |
| E'F' (EF = 3.46) | 2.4 | -1.06 | -30.64 | |
| H'I' (HI = 3.46) | 2.4 | -1.06 | -30.64 | |
| K'L' (KL = 3.46) | 2.4 | -1.06 | -30.64 | |
| **Tension to close (N)** | | | | 1.154 |
| First Z-plasty | | | | 0.214 |
| Second Z-plasty | | | | 0.204 |
| Third Z-plasty | | | | 0.191 |
| Fourth Z-plasty | | | | 0.545 |

**TABLE 7.** Outcomes of adding a gap between each Z flap of 1.0 cm (50% of central limb length).

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 11 | | | |
| A'B' (AB = 11.0) | 12.5 | 1.5 | 13.64 | |
| A'G' (AG = 2.5) | 3.1 | 0.6 | 24.00 | |
| G'J' (GJ = 3.0) | 3.2 | 0.2 | 6.67 | |
| J'M' (JM = 3.0) | 3.2 | 0.2 | 6.67 | |
| M'B' (MB = 2.5) | 3.0 | 0.5 | 20.00 | |
| **Actual length** | | | | |
| C'D" (CD = 3.46) | 2.2 | -1.26 | -36.42 | |
| E'F' (EF = 3.46) | 2.3 | -1.16 | -33.53 | |
| H'I' (HI = 3.46) | 2.3 | -1.16 | -33.53 | |
| K'L' (KL = 3.46) | 2.2 | -1.26 | -36.42 | |
| **Tension to close (N)** | | | | 3.171 |
| First Z-plasty | | | | 0.372 |
| Second Z-plasty | | | | 0.639 |
| Third Z-plasty | | | | 1.318 |
| Fourth Z-plasty | | | | 0.842 |

**TABLE 8.** Outcomes of adding a gap between each Z flap of 1.5 cm (75% of central limb length).

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 12.5 | | | |
| A'B' (AB = 12.5) | 15.2 | 2.7 | 21.60 | |
| A'G' (AG = 2.75) | 3.6 | 0.85 | 30.91 | |
| G'J' (GJ = 3.5) | 4 | 0.5 | 14.29 | |
| J'M' (JM = 3.5) | 4 | 0.5 | 14.29 | |
| M'B' (MB = 2.75) | 3.6 | 0.85 | 30.91 | |
| **Actual length** | | | | |
| C'D" (CD = 3.46) | 2.2 | -1.26 | -36.42 | |
| E'F' (EF = 3.46) | 2.2 | -1.26 | -36.42 | |
| H'I' (HI = 3.46) | 2.3 | -1.16 | -33.53 | |
| K'L' (KL = 3.46) | 2.2 | -1.26 | -36.42 | |
| **Tension to close (N)** | | | | 1.867 |
| First Z-plasty | | | | 0.665 |
| Second Z-plasty | | | | 0.47 |
| Third Z-plasty | | | | 0.381 |
| Fourth Z-plasty | | | | 0.351 |

**TABLE 9.** Outcomes of adding a gap between each Z flap of 2.0 cm (100% of central limb length).

| Parameter | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Result |
|---|---|---|---|---|
| **Actual length** | 14.0 | | | |
| A'B' (AB = 14.0) | 15.3 | 1.3 | 9.29 | |
| A'G' (AG = 3.0) | 3.6 | 0.6 | 20.00 | |
| G'J' (GJ = 4.0) | 4.1 | 0.1 | 2.50 | |
| J'M' (JM = 4.0) | 4.1 | 0.1 | 2.50 | |
| M'B' (MB = 3.0) | 3.5 | 0.5 | 16.67 | |
| **Actual length** | | | | |
| C'D" (CD = 3.46) | 2.2 | -1.26 | -36.42 | |
| E'F' (EF = 3.46) | 2.2 | -1.26 | -36.42 | |
| H'I' (HI = 3.46) | 2.2 | -1.26 | -36.42 | |
| K'L' (KL = 3.46) | 2.2 | -1.26 | -36.42 | |
| **Tension to close (N) total** | | | | **2.954** |
| First Z-plasty | | | | 0.713 |
| Second Z-plasty | | | | 0.680 |
| Third Z-plasty | | | | 0.887 |
| Fourth Z-plasty | | | | 0.674 |

**TABLE 10.** Measured parameters compared among the studied modified Z-plasty designs.

| Type | Original length (cm) | Actual length (cm) | Lengthening (cm) | Percent lengthening (%) | Total tension to close (N) ($cm^2$) | Area of distortion |
|---|---|---|---|---|---|---|
| **Conventional design** | 8.0 | 9.5 | 1.5 | 18.75 | 6.433 | 84.50 |
| **Angle 75 : 45** | 8.0 | 9.2 | 1.2 | 15.00 | 10.086 | 96.00 |
| **Angle 90 : 30** | 8.0 | 9.2 | 1.2 | 15.00 | 15.726 | 99.375 |
| **Size 2.5 switching 1.5** | 8.0 | 9.4 | 1.4 | 17.50 | 8.425 | 95.25 |
| **Limb size 2.5 &1.5** | 8.0 | 9.5 | 1.5 | 18.75 | 5.620 | 120.25 |
| **Add gap of 0.5 cm** | 9.5 | 10.9 | 1.4 | 14.74 | 1.154 | |
| **Add gap of 1.0 cm** | 11.0 | 12.5 | 1.5 | 13.64 | 3.171 | |
| **Add gap of 1.5 cm** | 12.5 | 15.2 | 2.7 | 21.60 | 1.867 | |
| **Add gap of 2.0 cm** | 14.0 | 15.3 | 1.3 | 9.29 | 2.954 | |

*Limitations*

Even though this experimental study was performed using a pig skin model, the authors propose that these findings may be extrapolatable to single and multiple Z-plasty procedures performed in human patients.

## CONCLUSION

Using a pig skin model, mathematical formulas were generated to predict Z flap percent lengthening, Z flap tension to close, and area of distortion. Addition of a gap 75% of the central limb length was the most efficacious Z-plasty configuration for increasing Z flap length and also better than many designs to reduce Z flap tension to close.

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