Some Thoughts on Choosing a Z-Plasty: The Z Made Simple

Donald A. Hudson, F.R.C.S.
Cape Town, South Africa

The Z-plasty and its variations are techniques commonly performed in plastic surgery. However, there are few descriptions and comparisons of the various types of Z-plasty. This article examines the mechanics of the Z-plasty and its variations. Understanding the geometry of the different variations will allow selection of the most appropriate Z-plasty for contracture release. (Plast. Reconstr. Surg. 106: 665, 2000.)

The Z-plasty is one of the most elegant techniques in plastic surgery. Surprisingly simple, yet incredibly effective, it is also one of the most versatile and widely used maneuvers in the specialty. The technique has a number of modifications. In addition to simple Z-plasties, there are multiple serial,1 four-flap,2 five-flap,3,4 and six-flap,5 double-opposing Z-plasties, and other, less commonly used modifications.6,7 These are not just theoretical extensions of the Z-plasty, but practical and applicable procedures.

Surprisingly, there are few articles comparing the different types and techniques of Z-plasty—despite the fact that it is one of the most commonly used maneuvers in plastic surgery. Even the major textbooks8–11 neither adequately discuss this aspect of the procedure nor give guidelines as to which Z-plasty to use.

Limberg12 produced a monograph on skin flaps that included the Z-plasty. The treatise was based on mathematical calculations. However, skin is an elastic structure that does not really follow the dictates of mathematical calculations, a premise that Furnas13–15 confirmed by performing some variations of the classic Z-plasty in animal experiments. To date, however, a comparison of different Z-plasties and indications for their respective selection has not been addressed.

Z-PLASTY MECHANICS

The usual Z-plasty consists of two identical triangular flaps that transpose synchronously with each other, recruiting tissue from one axis and redistributing tissue along another axis.16 Because the two flaps are adjacent and parallel, transposition produces lengthening in one direction (along the axis of the central limb) and shortening in another direction. For this to occur there must be sufficient tissue laxity to allow redistribution (as compared with the Heinecke-Mickulicz procedure, in which a longitudinal incision is closed transversely).

In comparison with the V-Y advancement flap, in which the tissue excess is in the same line as the direction of movement of the flap, the tissue excess of the Z-plasty will be redistributed mainly perpendicular to the desired axis of lengthening. The tissue is then transposed from the area of laxity to the area where it is required. For this reason, the Z-plasty is probably a more effective maneuver than a V-Y procedure. Therefore, in planning a Z-plasty, there are two fundamental questions to be answered:

1. How much tissue laxity is there adjacent to the contracture band or scar? The answer to this can be obtained from clinical examination. An examination of the quality and quantity of the skin (factors assessed by pinching the skin adjacent to the contracture band or scar) gives an indication of the degree of laxity.
2. In view of the above, which Z-plasty will...
derive the maximum benefit from this laxity? This article guides one to make the most appropriate choice.

APPLICATIONS

The Z-plasty is a procedure that is applicable to the following situations:

1. Realignment of tissues/shifting of topographical structures (Fig. 1). The Z-plasty is well known for realigning structures in which a step deformity has occurred. However, this technique is also helpful in moving tissue to a new position.

2. Release of contractures by increasing the length along the axis of the scar and breaking up the straight-line traction of the scar. Although all scars contract, some do so to such a degree that they distort adjacent or even distant structures. The Z-plasty breaks up the straight-line traction of the contracture and lengthens the scar forming the contracture. This outcome is achieved by recruiting tissue from an area of laxity and redistributing the tissue to the area where it is required. It is one of the most common uses of the Z-plasty.

3. Effacement of a web/creation of a cleft. When performing a Z-plasty on a contracture band/scar, the selection of a type of the procedure is usually required. (Although the procedural principles and mechanics are applicable to all three indications cited here, this article is primarily directed at the selection of a Z-plasty for contracture release.)

THE CLASSIC Z-PLASTY

In choosing a Z-plasty for a particular situation, there are certain considerations. The classic Z-plasty is designed with equal limb lengths\(^{16}\) and with 60-degree angles (Fig. 2, above). There are two ways the flap may be designed, depending on which direction the limbs take. The one variation (as a Z) is a mirror image of the other,\(^{11,16}\) which is the Z-in-reverse Z-plasty (backward Z). The classic Z-plasty can be modified in two ways, either by changing its size or by changing the angle.

The larger the Z-plasty flaps, the greater the lengthening obtained. However, the larger the two individual triangular flaps, the more difficult it is for them to be transposed and the more the tissue laxity required for lengthening to occur in one direction and for shortening to occur in the other direction. Furnas noted that the transposition of larger Z-plasties required seven to 10 times more tension to effect closure than a smaller Z-plasty.\(^{14}\)

When the angle of the Z-plasty is 60 degrees, the triangle is equilateral (i.e., the base and length of the flap are equal). A Z-plasty with an angle of less than 60 degrees implies that the

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**Fig. 1.** Using the Z-plasty to reorient tissue. The ala is displaced downward and laterally. A Z-plasty will reorient it into the correct position. Note that the apex of the one triangular flap (A) is placed (with transposition) at the base of the other limb of the Z-plasty (B).

**Fig. 2.** (Above) Classic Z-plasty with 60 degree angles, AB, lengthening of the central limb that is obtained in a vertical direction. CD, shortening that occurs in the transverse direction. If the length of the central limb (AB) was considered to be 1 cm, then the theoretical gain in length would be 75 percent. Therefore, the length of the central limb after flap transposition would be 1.75 cm. (Center) Z-plasty in series. Note that the central flaps have a somewhat square configuration. (Below) Schematic diagram of the double-opposing Z-plasty, which consists of a Z-plasty and a Z-plasty in reverse.
base of the flap is narrow compared with its length and, thus, its blood supply precarious. Narrow flaps (angle < 45 degrees) are tenuous from a vascular point of view. As the angle increases, so does the vascular safety of the flap. Although studies have been performed investigating 30- and 45-degree Z-plasties, these procedures have a limited applicability. Their vascular basis is tenuous, and the theoretical lengthening obtained minimal. A 45-degree Z-plasty yields a theoretical increase in length of only 50 percent (Table I). As the angle of the Z-plasty increases, the degree of lengthening increases. Studies have shown that a 60-degree angle increases the theoretical length of the central limb by 75 percent (Fig. 2, above), whereas a 90-degree angle increases the central limb by 120 percent, an increase that more than doubles original limb length (Table I). However, as the angle gets larger, the flaps become much more difficult to transpose. Thus, the flaps of a 90-degree Z-plasty are very difficult to transpose. Experimental work in animals has shown that the tension required to close a 90-degree Z-plasty is 10 times that required to close a 30-degree Z-plasty.14 As the amount of transposition increases, the dog-ear elevations that result from the wound closure also increase in size.

Despite its advantages, there are limitations to the classic Z-plasty procedure. These limitations include the following:

1. Actual length versus theoretical length. Although every plastic surgery resident knows that the classic Z-plasty enables a mathematically calculated increase in length of 75 percent, in reality, the outcome achieved in living tissue is much less. Skin is an elastic tissue, and the lengthening obtained depends on the relationship of the Z-plasty to the relaxed-skin tension lines, the anatomic site, the age of the patient, and other factors. Studies in vivo have shown an increase of only 40 to 60 percent of the mathematically predicted value. Experimental work by Furnas has also shown that, the larger the Z-plasty, the more the actual length approximates the theoretical length.14

2. The requirement for transposition and advancement of flaps. In ideal circumstances, the two flaps forming a Z-plasty represent simple transposition flaps. With the transposition of these flaps, shortening is effected in one direction and lengthening is effected in the other direction. However, ideal conditions are seldom present. More commonly, not only does transposition occur, but also some flap advancement is required to effect closure, thereby creating tension on the flaps with its attendant problems.

3. The hazard of the small Z-plasty. If the Z-plasty flaps are too small, insufficient lengthening of the contracted band occurs. Consequently, the contracture is not adequately released, resulting in the formation of a secondary band parallel to the original contracture. Hence, if the contracture is severe with little adjacent tissue laxity (i.e., there is insufficient adjacent lax tissue to allow the design of a large Z-plasty), contracture release with a skin graft for wound cover may be a better form of treatment.

4. Stereometric versus planimetric gain.17,18 This refers to the three-dimensional tissue effects of a Z-plasty on a flat surface (and on webs) and has particular relevance for scar revision on a flat surface. Transposition of the (stereometric) Z-plasty flaps produces elevations (dog ears) on a flat surface. Roggendorf proposed excising this excess elevated tissue and, in so doing, creating flat scars that are more cosmetically desirable; he called this modification the planimetric Z-plasty. He also

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**TABLE I**

A Simple Guide to the Theoretical Increase in Length of the Central Limb with Various Z-plasties

<table>
<thead>
<tr>
<th>Type of Z-Plasty</th>
<th>Increase in Length of Central Limb (%)</th>
<th>New Length of Central Limb (cm)†</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple 45-degree Z-plasty</td>
<td>50</td>
<td>1.5</td>
</tr>
<tr>
<td>Simple 60-degree Z-plasty</td>
<td>75</td>
<td>1.75</td>
</tr>
<tr>
<td>Simple 90-degree Z-plasty</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>Four-flap Z-plasty with 45-degree angles</td>
<td>100</td>
<td>2</td>
</tr>
<tr>
<td>Four-flap Z-plasty with 60-degree angles</td>
<td>150</td>
<td>2.5</td>
</tr>
<tr>
<td>Six-flap Z-plasty with 45-degree angles</td>
<td>150</td>
<td>2.5</td>
</tr>
<tr>
<td>Double-opposing Z-plasty*</td>
<td>75</td>
<td>1.75</td>
</tr>
<tr>
<td>Two Z-plasties in series*</td>
<td>75</td>
<td>1.75</td>
</tr>
<tr>
<td>Five-flap Z-plasty*</td>
<td>125</td>
<td>2.25</td>
</tr>
</tbody>
</table>

* These procedures are Z-plasties in series. For a given length of scar or contracture band, the limb length of the Z-plasty in series was shorter than that of the other variations, although the length of the central limb was 1 cm. The limbs of each Z-plasty were equal in length.

† The third column represents the length of the central limb after flap transposition; the original central limb of the Z-plasty measured 1 cm in length.
showed that little scar lengthening is obtained on a flat surface in vivo and that, when lengthening occurs, it is best achieved with a 60-degree angle Z-plasty. As a result, he recommended the planimetric Z-plasty for scars on a flat surface and the stereometric Z-plasty for effacement of a web.

5. Effacement of a web. This is almost a subject on its own for which only a few principles are mentioned here. When a Z-plasty is plotted on a web, each of the two triangular flaps lies in a different plane. After transposition, these flaps occupy new planes and the web is converted into a cleft. Furnas has shown that, when the peak angle of the web is 70 degrees and when the effacement performed uses 60-degree Z-plasty flaps, a tetrahedron is created. As a result, the web is deepened but not lengthened. This explains why the single Z-plasty has a limited application in first-webspace contractures, for example. Again, as the size of the Z-plasty increases, a deeper cleft is created. However, all of the problems associated with the large flap apply.

OTHER TYPES OF Z-PLASTIES

It is because of the above limitations that variations of the Z-plasty have been described, of which there are essentially two. In the Z-plasty in series, the scar is divided into multiple small Z-plasties. In contrast, in the Z-plasty in parallel, the length of the scar forms the central limb of one large Z-plasty. Each of the commonly used Z-plasty variations will be discussed and the geometry of each will be examined.

Multiple Z-Plasties in Series

In this procedure, the contracture band is divided into a number of segments, each with a Z-plasty designed in series (Fig. 2, center). It seems obvious that using multiple small Z-plasties in series is better than using one large Z-plasty, because the need for shortening width to give increased length is less when the Z-plasty is smaller. Consider a theoretical example in which a Z-plasty is required to give 2 cm of lengthening. A single large Z-plasty can be designed to yield 2 cm of lengthening, but this is associated with 2 cm of shortening along the transverse axis. However, if a series of four small Z-plasties is used (with each equal in size to a quarter of the single Z), then the lengthening obtained is still 2 cm but the shortening of the transverse axis is only 0.5 cm. As noted by McGregor, the lengthening obtained in series is additive, whereas the shortening is in parallel and, in this example, remains 0.5 cm. However, although to this technique is theoretically appealing, it has a number of limitations. One such limitation is that the actual lengthening obtained is much less than the theoretical lengthening, because the field of tension exerted by each Z-plasty impinges on its neighbor, in doing so limiting the overall gain in length. Another problem with multiple Z-plasties in series is that the central flaps have a somewhat square shape and, consequently, unlike triangles, do not interdigitate as easily (Fig. 2, below). A study by Roggendorf has shown that multiple Z-plasties, when applied to a web, lead to a sawtooth pattern.

The Double-Opposing Z-Plasty

This is a variation of two Z-plasty flaps in series, except that one Z-plasty is in the form of a Z-in-reverse Z-plasty (Fig. 2, below). This technique has the advantage that the flaps remain as triangles, interdigitating with ease. There is a single large flap in the center of the scar after transposition that has a wide base with an attendant, safer vascular basis. It must be stressed that these two variations of the Z-plasty do not lead to any length advantage (of the central limb) over the classic Z-plasty. When the length of the scar is 2 cm, a classic Z-plasty with equal limbs of 2 cm achieves the same amount of theoretical lengthening (2 cm × 75 percent = 3.5 cm) as two 1-cm Z-plasties in series (or a double opposing Z-plasty with limbs of 1 cm). This is because two Z-plasties in series have smaller (1 cm in the above example) limb lengths [lengthening is 2 (1 cm × 75 percent) = 2 × 1.75 cm = 3.5 cm]. The narrowing in the transverse direction is less with the Z-plasty in series; therefore, the two smaller flaps can be closed with less tension.

The Four-Flap Z-Plasty

This is a clever variation of the Z-plasty that has the advantage of gaining length in parallel (i.e., the gain in length of the central limb is that of two large Z-plasties). There are two types of four-flap Z-plasty, the 120-degree and the 90-degree, with each angle divided in half to create four flaps. These smaller flaps can be more easily transposed. Woolf and Broadbent
noted that Limberg described the Z-plasty flaps with angles of 60 degrees (Fig. 3). Simplistically, this would yield a theoretical increase in length of $2 \times \frac{1}{2}$ of 60-degree Z-plasties in parallel ($2 \times 75\% = 150\%$) (Table I). They recommended the implementation of four flaps, each with 45-degree angles (Fig. 3). This would lead to a double-fold increase in length of the central limb ($2 \times 50\% = 100\%$) (Table I).

The Five-Flap Z-Plasty

This is actually a double-opposing Z-plasty (a Z-plasty in series) with the addition of a V-Y plasty between the two (Fig. 4, above). This variation has the advantages of both the Z-plasty and the V-Y advancement flaps. One disadvantage of the technique is that the central flaps are somewhat square, a shape that may transpose with more difficulty. The theoretical lengthening obtained is 75 percent for the double-opposing Z-plasty, plus 50 percent for the V-Y plasty, equalling 125 percent (Table I). Note that, for a given length of scar (e.g., 2 cm), the limb lengths of the four-flap Z-plasty (with each limb 2 cm in length) are twice as large as those of a five-flap Z-plasty (with each limb 1 cm in length). Awareness of the difference between the Z-plasty in series and the Z-plasty in parallel is key to understanding why the four-flap Z-plasty leads to a longer scar. Of course, because the limbs of the four-flap Z-plasty are much larger, it requires much more laxity of the adjacent tissue to effect. Thus, the four-flap Z-plasty may be a good option when there is sufficient tissue laxity to allow its design. When there is less tissue laxity, the five-flap Z-plasty may be considered a better choice.

The Six-Flap Z-Plasty

This procedure is similar to the 45-degree four-flap Z-plasty, but with an additional limb (Fig. 4, below). Hence, it could also be considered another variation of the Z-plasty in parallel. Simplistically, the theoretical gain in length of the central limb is $3 \times 50\% = 150\%$, which is well more than a doubling in length (Table I). Like many of the other Z-plasties, it creates a symmetrical zigzag once transposed and is indicated for the release of short, contracted bands. This technique recruits maximally from the adjacent tissue; as a result, transposing the flaps is often difficult and dog-ears occur frequently. The variations of the Z-plasty in parallel are better applied to shorter scars. The multiple Z-plasty in series has the advantage that it can be applied to any length of scar.

The Single-Limb Z-Plasty

This involves the transposition of a simple, triangular flap to another area. One example of its use is in the treatment of medial ectropion of the lower eyelid from a contracted vertical scar. The excess tissue from the upper eyelid is transposed to the lower eyelid, where there is a shortage of tissue (Fig. 5, above). If the flap is too narrow or too long relative to its base, then its tip is susceptible to ischemia. The single-limb Z-plasty does not offer the mechanical advantages of the classic Z-plasty.

The Dancing-Man Procedure

This was described by Mustarde for the treatment of epicanthic folds with or without
telecanthus (Fig. 5, below). Chapman et al. considered the procedure to be a type of five-flap Z-plasty, but it can also be interpreted as a modification of the double-opposing Z-plasty (Fig. 5, below). However, unlike that technique, the Z-plasties in the dancing-man procedure are oriented obliquely to each other and share a common central limb rather than being arranged along a straight line. Also, rectangular rather than triangular flaps are interdigitated; thus, more tissue is transposed in this procedure than with a classic Z-plasty. The dancing-man technique has also been applied in the release of skin contractures.

In the past, plastic surgeons spent a considerable amount of time learning the geometry of simple skin flaps. Today, plastic surgeons are consumed with learning the many new techniques available, with not enough time devoted to understanding the mechanics of a procedure. Thus, in choosing the most appropriate Z-plasty for a particular situation, the surgeon needs to critically assess the degree of laxity of the adjacent skin and to understand the mechanics of the various Z-plasties. It should be emphasized that no type of Z-plasty makes more skin; the procedure merely narrows the tissue in one axis and lengthens it in a perpendicular direction. The Z-plasty in parallel leads to more lengthening, but at the expense of more transverse shortening. In contrast, the Z-plasty in series does not require as much laxity of adjacent tissue to effect, but it also offers less of a gain in length.

It must be remembered that the potential for lengthening, although widely expounded in textbooks, only gives the theoretical gain in length of the central limb of the flap. The actual gain may be considerably less. Hence, regardless of which variation is chosen, the Z should (in theory) always be as large as possible. This is an important factor to remember when attempting to increase length of a scar in vivo.

The application of the Z-plasty, like all plastic surgery procedures, requires thought and planning. It is preferable to avoid a situation such as the one described by Chapman et al. in which a Z-plasty used to correct a severe adduction contracture of a thumb resulted in a cleft of the first web space rather than a restoration of the thumb-finger excursion.

Donald A. Hudson, F.R.C.S.
7 Kelvin Road
Newlands
Cape Town 7700
South Africa
dahudson@masa.co.za

REFERENCES


