Z- plasty: The twin transposing symmetrical flaps

Dr Vigneswaran V, vigneshdr87@gmail.com**,** Registrar
Dr Praveen Bhardwaj, drpb23@gmail.com**,** Consultant
Department of Plastic, Hand and Reconstructive Microsurgery
Ganga Hospital, Coimbatore

It is not often we find one of the oldest techniques in plastic surgery to be widely published in every plastic surgery textbooks all these years, described for revision of scars without excision of the scar tissue. In other words, utilising the scar tissue for revision of the scars. So much simpler, pliable and versatile, are these Z- plastic operations, that they occupy a definite place in the range of treatment options for any contracted tissue.

History

The origin of Z- plasty was rooted in ophthalmic operations with reports of ectropion correction using Z shaped incisions by Horners[1](1837) and Denonvilliers[2](1854). However, the concept of two triangular flaps with equal length and equal angles transposed into each other's defect was put forth by Berger[3] in 1904. Stewart Leroy McCurdy, a General, Oral, Orthopaedic and Plastic Surgeon, in 1913 published a report of elongating scars, christening the procedure as Z-plastic operations[4]. Since then, this procedure majorly performed in face and neck, creeped into hand surgery. In 1914, Morestin corrected a flexion deformity of the finger with multiple Z shaped incisions which appears to be the prime instance of multiple Z-plasty[5]. In the following decade, Pieri, Steindler, Bosch Arana and Babcock utilised the modified Z shaped incisions in releasing the web between thumb and index finger in different instances. Limberg, strengthened the mathematical basis of these flaps[6] in his multiple monographs and Davis popularised the technique with numerous publications.[7,8] In 1946, McIndoe introduced Z- plasty in Dupuytren's contracture, where it offered the best solution both for wider exposure and addressing the skin deficiency[9]. In 1967, Ian McGregor[10] published the most cited paper on the role of Z- plasty in Hand surgery which elaborated the role of this ingenious technique in Dupuytren's contracture and skin contractures with their limitations in hand where the availability of skin to transpose is the least compared to the other parts of the body.

The Basic Z- plasty

Symmetry is the cornerstone of a successful Z- plasty. Three equal length incisions and two equal degree angles constitute the classical Z- plasty. One of the incision, the central limb is placed along the line of contracture (or along the fusiform defect following excision of the scar) and the other two, the lateral limbs are placed at either end of the central limb at an equal angle. The two triangular flaps are raised and their transposition results in the central limb reorienting perpendicular to the previous position with concurrent increase in the length. The gain in length comes at the expense of equal amount of transverse shortening of the adjacent tissue.

Surgical technique:

The classic Z- plasty: It is always worthwhile to perform the proposed Z- plasty on a piece of paper before proceeding clinically. The incisions are marked on the scar with the central limb drawn along the most prominent part of the scar and the lateral limbs are laid out parallel to each other at the ends of the central limb, all three of equal lengths in opposite direction, each at an angle of 60º to the central limb. Such planning is particularly helpful while releasing contracture bands in the hand where the 'Z' can be designed in a way that the reoriented contracture comes to lie along the skin crease or flexor crease. When the contracture band is thick and rigid, it is excised and the resultant defect acts as the central limb. Once the incisions are made over the markings, two broad based triangular flaps are formed with their bases opposite to each other. The flaps are mobilised thoroughly, releasing the binding scar underneath as completely as possible and ensuring hemostasis. It will be now evident that the scar tissue pulls away the corners of the central limb, elongating it and the earlier sharp angles of the lateral limbs become rounded or blunt. Frequently it is noticed that, when the flaps are mobilized, they transpose themselves and fall into their new positions.The flaps are then transposed with minimal handling using a skin hook and sutured without tension in such a way that their outer margins are approximated and their tips reach the outer corner of the bases of the opposite flaps. Once the flaps are sutured, a 'Z' is formed but an elongated one, reoriented at an angle of 90º to the original with the central limb now lying transversely across the line of scar. Tip necrosis or sloughing is the common complication observed, which can be alleviated by raising a thick flap. It should not be alarming as the sloughing is mostly superficial and will heal secondarily.

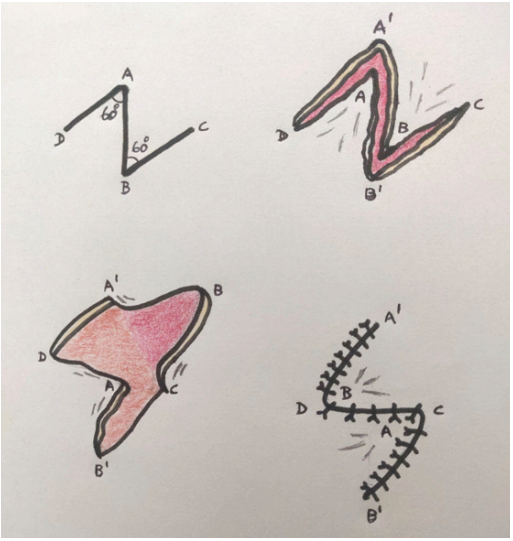

Fig. 1: The classic Z- plasty

Technical considerations

The anatomic location: What are all the places, a Z- plasty can be carried out? Any part of the body which can provide slack tissue to cope with the transverse shortening that inevitably follows the procedure. However, the palm and the digits are provided with skin that is reluctant to move or turn. Hence technical modifications are required to perform a Z- plasty in the hand which will be discussed in subsequent sections.

The angles and the lengths: Once the central limb length is fixed, the size of the angle determines the lengthening that could be achieved. The angle could be anywhere between 30 degrees to 120 degrees with 25% gain in length for every 15 degrees increase in the angle. However these calculations are theoretical as multiple factors like pliability of the skin, skin tension forces and scarring confront the clinical situation. In reality, the gain in length achieved ranges between 55% to 84% of the predicted value[11]. The length of the limbs are majorly determined by the tissue available on either side of the limb. In fingers, a Z- plasty of the size that could be fit in the adjoining phalangeal segment, will result in transverse shortening affordable by the local tissue.

Why 60 degrees is the commonly chosen angle: A 30 degrees Z- plasty will result in 25% gain in length with narrower flaps endangered with compromise in the blood supply to the flap. In contrast, flaps with angle more than 60 degrees, though provides a larger gain in length, require equal amount of tissue

available to account for the transverse shortening which is seldom available. It has been found that with increased angle beyond 60 degrees, the tension in the surrounding tissue seldom allows the flaps to be transposed. For example, a 90 degree Z- plasty will result in 120% gain in length theoretically. However the tension required for the transposition of the flaps and skin closure is estimated to be ten times that of the tension required to close a 30 degrees Z- plasty[11]. With such increased tension, these flaps are deemed to fail with undesirable outcomes. Hence for a desired appropriate gain in length, with flaps of adequate size that can be transposed readily without tension, 60 degrees remains the chosen angle.

When every descriptions of Z- plasty to date boast about the equal length of the limbs, one stand alone description by Yanai, in 1986, in a seemingly logical manner illustrated that the central limb or the trunk of a Z- plasty should be longer than the lateral limbs[12]. He used a sponge rubber model instead of a paper model and tells that the limbs can all be of equal length only when there is no contracture. In the presence of contracture, the central limb becomes shortened once the scar tissue is excised.

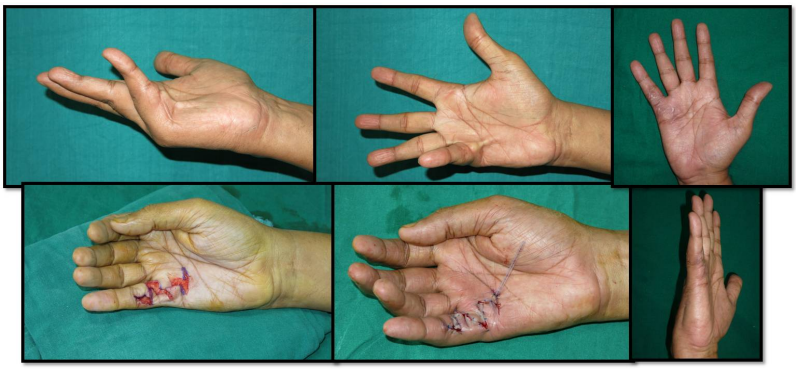

Fig. 2: Z- plasty in correction of Dupuytren's contracture

Thickness of the flap: The flap should contain full thickness skin containing the dermis. This prevents secondary wound contracture. Including the subcutaneous fatty tissue in the flaps will make the flap transposition difficult or impossible. Thus an ideal plane for the flap elevation lies in between the subdermal and subcutaneous tissue.

Mathematics and Z- plasty: The two triangular flaps were reconstructed into a parallelogram by Limberg, whose mathematical descriptions of Z- plasty remain few of the most cited publications in the literature. The shorter diagonal lies in

the line of contracture and the longer or the transverse diagonal indicates the position of the reoriented scar. The difference between these diagonals indicate the amount of lengthening possible. Furnas, through his elaborate studies on dogs dictated the biomechanical consequences effected with variations in Z-plasty which can be summarised as follows: more force is required for closure with longer Z- plasty, 90 degrees Z- plasty requires 7-10 times the force for closure compared with 30 degrees Z- plasty, greatest lengthening was seen with fewest number of Z- plasty and larger flap size, and lastly actual lengthening was always less than that of geometrically predicted[11]. Gibson and Kenedi (1967) who measured the lengthening from Z-plasties in patients, discovering that lengthening ranged from one-third less to two-thirds more than expected from their geometrical calculations[13]. Calculation of the length that can possibly be gained with Z- plasty initiated a surge of mathematical equations which appear to perplex the surgeon. McGregor derived that the percentage lengthening that can be gained solely depends on the Z- plasty angle and with change in angle the length varied as explained as $(\sqrt{5}–4 \cos ø)$-1 X 100, where ø is the Z-plasty angle[14]. Rohrich used the Pythagorean dictum of equilateral triangles, $A^2 + B^2 = C^2$ and concluded that the final length of contracture after Z-plasty is $\sqrt{3}$ of the original contracture length[15]. In an easier way, with a 60º Z- plasty, the final length is approximately 7/4 times of the original length. It has been proposed whether a contracted scar requires multiple Z- plasties can be identified by measuring the laxity of the adjacent skin. The laxity is divided by $\sqrt{3}$ or 1.73 to dictate of the length of the Z- plasty limbs. If the laxity is equal or more than the length of the scar, then a single Z- plasty will suffice[16].

Variations

In the earlier days when Z- plasty was routinely used to treat congenital deformities, where the skin is of normal texture, as in constriction band syndrome or incomplete syndactyly, a classic Z- plasty would suffice to correct the deformity. However, in most of the instances, the deformity is secondary to trauma and burns where the normal skin is partially or completely replaced by scar tissue. Treating them calls for exploitation of the versatility of Z- plasty. The principles of this technique can be expanded to correct such deformities as seen below.

1. Z-plasty of unequal angles: In clinical practice, on many occasions, the Z-plasty has to deal with tissues that are totally replaced by scars or skin infiltrated with scar tissues. In such conditions, the lateral limbs of the classic Z-plasty, have to be drawn at unequal angles from the central limb. In this way, the normal skin can be brought into the scarred tissues. Furnas noted that in this variant, the narrow flap required less tension for closure but is subject to more distortion and the wider flap led to greater strain in surrounding tissues.

The central limb is placed along the margin of the scar tissue and one of the lateral limb is drawn into the scar tissue perpendicular to the central limb and the other drawn at an angle of 60 degrees. The contracted scar is released and the narrower flap with normal skin is then wedged between the scar tissue with increase in length proportional to the central limb. Kamolz constructed a Z- plasty with 90º- 45º angles and named them "3/4 Z- plasty to be used widely in axillary contractures[17].

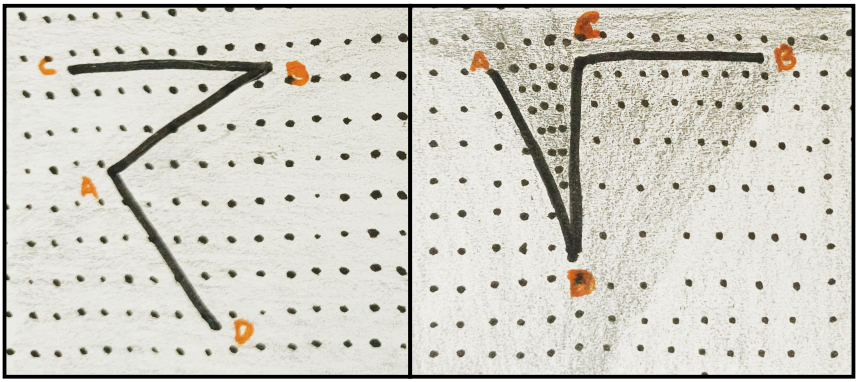

Fig. 3: Z- plasty of unequal angles. The strain on the wider flap to be noted

2. Multiple/ Compound Z- plasty: It is well known that the increase in length of the contracture is always followed by shortening in the transverse direction. The luxury of having lax skin to accommodate the shortening is not omnipresent, especially in the hands. For instance, with a single Z- plasty,two cms gain in length will demand for two cms shortening in the transverse di-

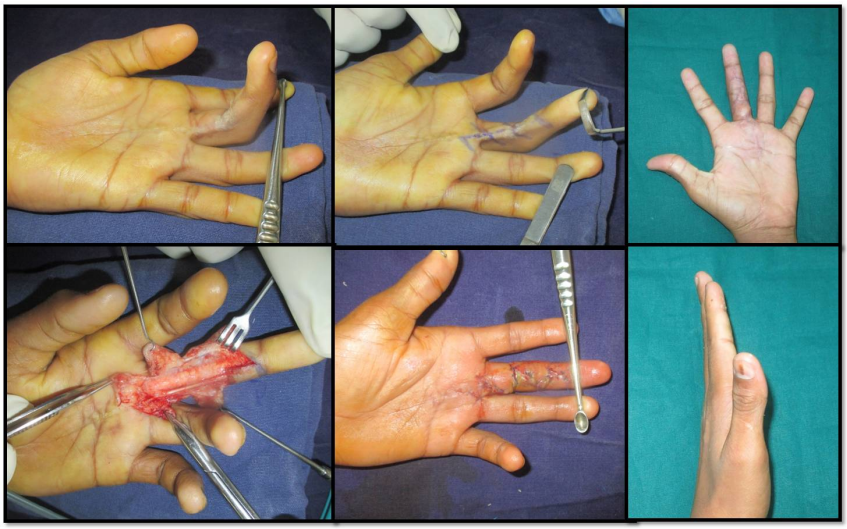

Fig. 4: Multiple Z- plasty for flexion contracture of fingers

rection, which will never be available in the hand. It can be effectively overcome by dividing the contracture band into smaller equal segments, for example, two segments and constructing Z- plasties in each segment. Here the lengthening achieved from each segment adds on to the desired lengthening with shortening only about half of that occurs with single Z- plasty. It is additive that, with multiple Z- plasties, the amount of movement required to transpose the smaller flaps is also reduced proportional to the number of segments used. When using multiple Z- plasties in digits, the successive Z-plasty should be smaller than the previous one as the digits become narrower from proximal to distal with the phalangeal segments becoming smaller and the tissue that can be mobilised diminishes in the same fashion[10]. The redundant tissue while passing from one to another Z- plasty should not be excised and is allowed to settle down to form the natural bulkiness.

3. Double opposing Z- plasty: Two Z- plasties, mirroring each other can be constructed adjacent to each other, based on the same central limb in areas of limited skin availability. Though there will not be superior gain in the lengthening achieved with the above mentioned techniques(75%), the broad based central flap after transposition effectively increase the safety margin of viability when vascular sufficiency of the scar tissue is questionable. Shaw and colleagues described the interdigital butterfly flap based on this technique[18], useful in treating the webbing between digits secondary to burn contractures, Dupuytren's contracture and syndactyly. They found that, with this technique, lengthening happened in both transverse and vertical planes and the web became deeper too.

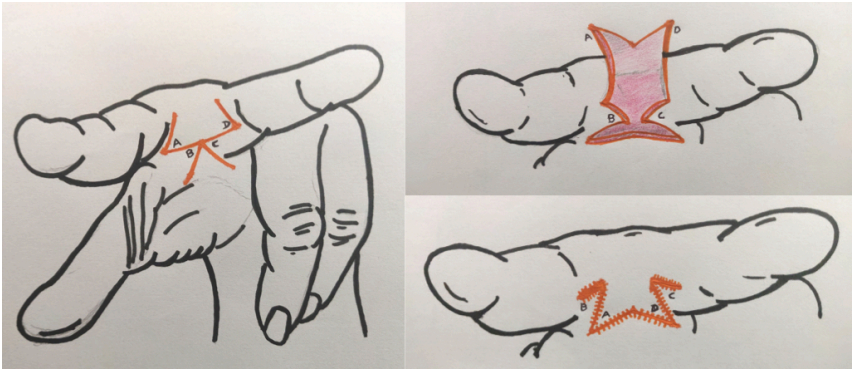

Fig. 5: Double opposing Z- plasty

4. The four flap Z- plasty: Limberg in 1929, described this technique, where a classic Z- plasty is drawn with lateral limbs at an angle of 60º. Each of this angle is divided into two thus creating four flaps with tip angle of 30º each. The theoretical gain obtained with this technique is 100%. Woolf and Broadbent extrapolated this technique and used limb angles of 90º resulting in four flaps of 45º each and gain in length of 150% which could be significant in areas where the mobility of the skin is grossly limited[19].

5. The five flap Z- plasty: Hirshowitz, in 1975 described the technique combining the effects of a double opposing Z- plasty and Y-V advancement[20]. The technique is based on the principle of Z- plasty of unequal angles. The central limb is marked over the length of the web. The 'V' component is marked on the side with lax skin. The lengths of the limb depend on the desired deepening and should be equal to half the length of the central limb. Angles of 80º and 60º are used as shown resulting in smaller flaps which can be easily transposed. After transposition, some trimming is required for proper inset. There is only minimal narrowing in the palmar and dorsal planes with the theoretical gain along the contracture sums up as 75% for the double opposing Z- plasty and 50% for the Y-V advancement. He concluded that the five

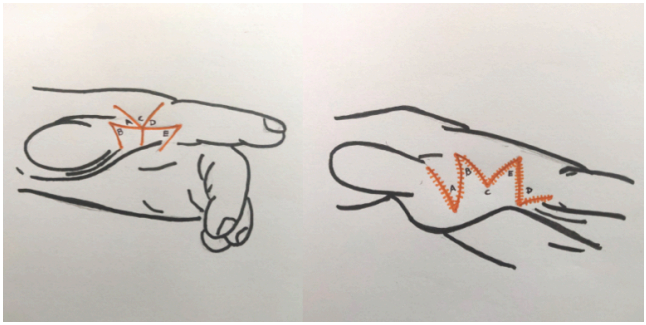

Fig. 6: Five flap Z- plasty for first web release

flap Z- plasty can be effectively used in releasing superficial webbing or contracture of the first web space. He also found that this method to be similar to the one described by Mustarde in 1971 for the correction of medial epicanthus[21]. However the flap had an additional limb between the central limb and the 'V' component very much resembling a ' jumping man'. It is to be noted that with the four flap Z- plasty, the limbs are of equal lengths which mean it requires the availability of more skin to be mobilised than that with the five

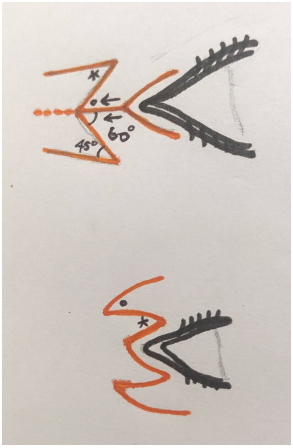

Fig. 7: The Real 'Jumping Man' flap

flap Z- plasty where the limbs of Z- plasty are only half the length of the central limb.

6. Tetrahedral Z- plasty: One of the four fundamental functions of Z- plasty- apart from lengthening, break up a straight line and shifting the topographical features as noted by Furnas was effacement or elimination of the web[22]. He proposed the tetrahedral model for the same where the classic Z- plasty is constructed across two different planes (palmar and dorsal in case of first web) which following transposition comes to lie in two newer plane unlike a normal Z- plasty which forms the mirror image of the original. There is no lengthening or shortening seen with this method but only deepening a web or obliteration of a cleft[23]. However with the arrival of more easier techniques, the tetrahedral Z- plasty finds limited space in management god web contractures.

Summary

Thoughtful planning and mastering the execution remain the heart of a successful Z- plasty. When utilised properly, the technique can result in the complete use of tissues, which otherwise would be discarded, in a reconstructive manner. It is simpler and can produce results similar to other methods of scar revision when executed successfully with marking the limbs and angles before incision, raising flaps of appropriate thickness, minimal handling of the flaps, visualising the final position of the flaps and appropriate inset.

References

1. Horner WE. Clinical report on the surgical department of the Philadelphia Hospital, Blockley for the months of May, June and July 1837. Am J Med Sci 1837;21:99.
2. Denonvilliers CP. Blepharoplastie. Bull Soc Chir Paris 1856;7:243.

3. Berger P, Bonset S. Traitments de de´forma-tions conse´cutives aux cicatrices vicieuses de l'e´paule. Chir Orthop Paris 1904;16:180.
4. McCurdy SL. Z-plastic surgery. Surg Gynecol Obstet 1913;16:209.
5. Morestin H. De la correction des flexions permanentes des doigts. Rev Chir 1914;50:1–27.
6. Limberg AA. Skin plastic with shifting triangle flaps. Collect Sci Works Mem Of 1929;50:862.
7. Davis JS. The relaxation of scar contractures by means of the z-, or reversed z-type incision: stressing the use of scar infiltrated tissues. Ann Surg 1931; 94(5):871.
8. Davis JS. Present evauation of the merits of the z- plastic operation. Plast Reconstr Surg 1946;1(1): 26–38.
9. Gosset J. Treatment of Dupuytren's disease by MacIndoe's technique. Mem Acad Chir (Paris). 1951 Mar 14–Apr 4; 77(10–11):312–8
10. Mcgregor, IA. The Z-plasty in hand surgery. J Bone Joint Sure Br. 1967, 49: 448-57.
11. Furnas DW, Fischer GW. The Z-plasty: biomechanics and mathematics. Br J Plast Surg 1971;24:144–60.
12. Yanai, A., Nagata, S., Okabe, K. The Z in Z-plasty must have a long trunk. Br J Plast Surg. 1986;39:390–394
13. Gibson, T. and Kenedi, RM. (1967). Biomechanical properties of the skin. Surgical Clinics of North America, 47, 279-294.
14. McGregor, IA. (1957). The theoretical basis of the Z-plasty. British ffournal of Plastic Surgery, 9, 256-~59.
15. Rohrich, RJ., and Zbar, RI. A simplified algorithm for the use of Z-plasty. Plast. Reconstr. Surg. 103: 1513, 1999.
16. Ellur S. A mathematical model to predict the requirement for multiple Z plasties. Indian J Plast Surg 2008;41:99.
17. Kamolz LP, Huang T. Reconstruction of burn deformitites: an overview. In: Herndon DN, editor. Total burn care. 4th edition. Philadelphia: Elsevier; 2012. p. 571–80.
18. Shaw DT, Li CS, Richey DG, et al. Interdigital butterfly flap in the hand (the double-opposing z-plasty). J Bone Jt Surg Am 1973;55(8):1677–9.
19. Woolf RM, Broadbent TR. The four-flap z-plasty. Plast Reconstr Surg 1972;49(1):48–51.
20. Hirshowitz, B., Karev, A., and Rousse, M. Combined double Z-plasty and V-Y advancement for thumb web contracture. Hand 7: 291, 1975
21. Mustarde, JC. Repair and Reconstruction in the Orbital Region, 2nd Ed. Edinburgh: Churchill Livingstone, 1980. Pp. 334–342.
22. Furnas DW. The four fundamental functions of the X-plasty. Arch Surg. 1968;96:458–463.
23. Furnas DW. The tetrahedral Z-plasty. Plast. Reconstr. Surg. 35: 291, 1965.