Analysis and evolution of rotation principles in unilateral cleft lip repair

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Summary Unilateral cleft lip repair, over the last century, has seen both revolutionary changes and subtle technical refinements. Millard’s rotation/advancement technique stands among the most striking of these innovations. We review the evolution of unilateral cleft lip repair including a look at straight-line, geometric and rotation/advancement type of repairs, while looking closely at the underlying theme of rotation and how common principles are evident in differing techniques. A review of how the medial cleft lip element is lengthened in these differing approaches illustrates common principles that, if learned and applied, will aid both the novice and experienced surgeon approach repair of the unilateral cleft lip in the lifelong quest of improved outcomes.

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Cleft-lip repair has evolved largely in the past 100 years to its modern form. We examine one crucial element, that of rotation, in a broad, but by no means all-inclusive, review of unilateral cleft lip repair. This analysis illustrates differing methods of lengthening the medial cleft lip element; in effect, taking two unequal lines and making the shorter as long as the other. More than just historically significant, a close look at this evolution illustrates common principles of rotation and is instructive to both the novice surgeon interested in learning cleft lip repair as well as to the skilled surgeon interested in refining and improving his or her skills.

The unilateral cleft lip deformity reveals two-thirds of the philtral unit to be essentially intact. The peak of the Cupid’s bow, however, is rotated apically along the cleft margin of the medial lip element as a result of short vertical lip height which also leads to a shortened cleft-side philtral column. The cleft-side peak of the Cupid’s bow is usually recognizable. Re-establishing a natural and symmetric-appearing lip and nose is best achieved when lip and nasal subunits are
preserved and incisions hidden along lines parallel to highlights and shadows around the philtral, columellar and alar subunits; restoring shape and function to the underlying muscular sling while minimizing potential growth disturbances. The difference between cleft philtral column height and non-cleft philtral column height determines the amount of downward rotation needed in order to re-establish cleft-side vertical lip length and a natural appearing Cupid’s bow and philtrum, and how that rotation is achieved largely differentiates techniques and types of repairs.

Discussion

Straight-line repairs

A recent survey of 269 responding North American cleft teams performing cleft lip surgery reported only 1% using straight-line repair for complete cleft lip and 2% for incomplete cleft lip. Rose (1891) (Figure 1a), and later Thompson (1912), developed repairs in which curvilinear incisions along the cleft margins are used to gain vertical lip length, allowing a degree of lengthening that occurs as the medial lip is rotated down and the incisions straighten out. There is potential for scar contracture and the sacrifice of excess normal tissue along the cleft margins in order to achieve straight-line closure as well as blunting of the shape of the Cupid’s bow.

Chait recently (2007; Figure 1b) proposed a straight-line technique in which the cleft-side philtral column incisions are well camouflaged. Rotation is possible because of a V-shaped wedge excision along the cleft margin, but in order to achieve adequate lip height the cleft-side incision extends beyond the point of the Cupid’s bow peak on both cleft and non-cleft sides and, as a result, the Cupid’s bow is similarly blunted.

Pfeifer (1970; Figure 1c) described a wavy-line repair that allowed downward rotation as the curves were approximated into a straight line. Nakajima’s design (2008; Figure 1d) curves away from the cleft margin of the medial lip philtral ridge to achieve rotation. For larger clefts, an inferior triangle flap above the vermillion allows for additional rotation, although Nakajima has recently described an inferiorly based semi-circular flap. These subtle modifications are founded on geometric/triangle-flap principles in which excess lateral tissue just above the white roll is borrowed to fill in rotational defects of the medial lip.

Delaire’s cleft lip technique (1975; Figure 1e) borrows from many other techniques and is not strictly a straight-line repair. It incorporates a curvilinear incision that extends up and parallels the medial cleft margin but stops near the medial edge of the base of the columella. The lateral lip element advancement incision curves outward and then medially as it extends superiorly before it again extends laterally around the alar margin. When closed, the inferior portion of these incisions, similar to the undulating Pfeifer repair, allow for a relatively straight-line incision along the philtral ridge as the shortened medial lip is rotated down. Again, a small inferior back-cut along the medial lip and laterally based inferior triangle are often needed to achieve additional rotation.

In the aforementioned survey, the Nakajima technique was included under the triangle-flap category and this represented an additional 1/269. The Delaire repair was employed in 2% of the procedures for both complete and incomplete unilateral clefts and was included in its own separate category. Despite the relatively small number of surgeons using straight-line techniques, these techniques illustrate the common principle that curvilinear incisions allow for rotation and increased lip length with resultant straight-line or near-vertical incisions.

It is worth noting that the medial and lateral lip-element incisions do not necessarily begin as straight incisions and that it is only as the vertically short medial lip is rotated downward and approximated with the lateral lip incisions that the overall appearance begins to appear more vertically oriented with respect to the philtral column and approach a semblance of being straight.
Geometric designed techniques

Geometrically designed flaps are common to many cleft lip repair techniques but, generally, a repair type is only classified as geometric when the final scar disrupts the vertical philtral column in a zigzag fashion. Mirault (1844) is credited as being the first to have used a flap along the inferior aspect of the lateral lip element that then crossed the cleft filling in the resultant rotational defect and thereby added vertical length to the medial lip element.¹⁰ This technique did not pay attention to recreating the Cupid’s bow.

The quadrangular flap
LeMesurier’s¹¹ technique (1955; Figure 2a) uses a back-cut above the Cupid’s bow and a laterally based inferior rectangular flap to fill in the rotational defect of the medial lip element thereby re-establishing vertical height and the Cupid’s bow with a series of right-angled incisions which disrupt the inferior aspect of the cleft-side philtral column and central aspect of the philtral subunit.

Triangle-flap techniques
Nine percent of 269 North American cleft teams reported using triangular flap techniques in unilateral cleft lip repair; these comprised 48% Randall—Tennison, 28% Fisher subunit, 4% Nakajima and 12% Davies Z-plasty.¹

Both Tennison,¹² (1952; Figure 2b) and Randall’s¹³ (1959) mathematical modifications of the triangle-flap repair are conceptually similar to LeMesurier’s technique. Trauner (1950; Figure 2c), Skoog (1958), Cronin (1966), Malek (1983) and Nakajima (1993) devised triangle-flap techniques some of which use more than one laterally based triangle.¹⁴—¹⁸ Song (1982; Figure 2d) employed a superiorly based lateral triangular flap advanced into a back-cut across the columellar base which he termed an ‘inverted Tennison repair’.¹⁹ The final scars of this technique are similar to the Millard rotation/advancement technique. Triangular flap techniques involve one or more back-cuts placed along the medial lip cleft-side philtral ridge and one or more lateral lip-element triangular advancement flaps to fill in the resultant defect(s) as the medial lip element is rotated down. Tennison’s technique made use of an inferior back-cut that began not far above the cleft-side peak of the Cupid’s bow of the medial lip element and angled superolaterally. Theoretical advantages for geometric techniques include applicability to a wide range of cleft sizes; the ability to symmetrically recreate the Cupid’s bow; achieve adequate rotation, lip length, increased fullness of the philtral tubercle as well as minimal wasted tissue in such repairs. Because of the ability to geometrically design precise flaps, such techniques are relatively easy to teach and learn.²⁰ Precisely measured triangle flaps allow vertical lengthening of the medial lip element while enabling lengthening of what is often an otherwise short transverse lateral lip element without compromising the ideal basal position of the philtral column incision.²¹

Davies (1965), and reports of modifications by surgeons such as Fernandez (Figure 2e), described using small triangular flaps transposed from lateral and medial lip elements in Z-plasty fashion.²² Downward rotation is achieved as these flaps are transposed across the cleft. The cleft itself represents the central limb of the Z-plasty, whereas the size and angle of lateral limbs with respect to the cleft margins determine the theoretical vertical lengthening and downward rotation that occur as tissue perpendicular to the cleft margins is transposed across the cleft. Vertical lengthening is achieved as the soft-tissue aspects of the cleft are narrowed transversely. As with any Z-plasty, there is often an element of advancement which occurs in addition to transposition.²³ The transposed skin incisions of a Z-plasty repair may closely resemble the C-flap and the lateral advancement elements of rotation/advancement techniques.²⁴

Rotation/advancement repairs
Millard’s initial technique proved revolutionary in unilateral cleft lip repair. While several surgeons before Millard had
employed both elements of rotation and advancement in their techniques, Millard’s innovation lay in designing incisions that allowed for rotation but also minimized disruption of aesthetic subunits. The fact that 46% of North American surgeons report using the Millard rotation/advancement technique without modifications for unilateral lip closure and another 38% performed rotation/advancement techniques with various modifications is a testament to the success of this technique in camouflaging incisions. As initially described (1955), and published (1957), the incision ascends superiorly along the medial lip-element cleft-side peak of the Cupid’s bow mirroring the contour of the contralateral normal philtral column. The incision then bowed in a curvilinear fashion near the base of the columella crossing the philtrum towards the far lateral extent of the columellar base. This gentle convex slope was affected in order to achieve length to the cleft-side philtral column and allow the medial lip element to be rotated down. Alone, this maneuver was often insufficient to achieve adequate rotation and lip height and, subsequently, an inferiorly oriented back-cut was added (1960; Figure 3a) at the base of the columella that extended down and parallel to the unaffected philtral column. Despite well-camouflaged incisions, the upper portion of the philtral subunit is often disrupted by the lateral advancement flap creating a scar that crosses the upper third of the cleft philtral column. In wide clefts, achieving the necessary advancement to fill in the rotation defect frequently narrows the nostrils or results in an unsightly incision around the alar base. Peri-alar incisions may also efface the natural alar—facial groove, a deformity made more noticeable with smiling.

Mohler (1987; Figure 3b) extends the rotation incision up into the base of the columella before executing a back-cut in order to achieve added rotation. Tatum (2007) describes a two-staged approach. The first stage is essentially a full-thickness straight-line closure, no different from an adhesion except that the orbicularis muscle is freed up and included in the closure. As with an adhesion, no effort is made to lengthen the short cleft-side medial lip element. During the second stage, as depicted in (Figure 3c), an incision is designed along the cleft margin up to the columellar base and then back cut perpendicular and along the base of the columella in order to achieve rotation. The C-flap, which is laterally based, fills in this rotational defect.

A recent survey of 20 late Millard repairs found that 50% were unhappy with their scars in the upper one-third and 35% were unhappy about the lower one-third of the scar where peaking was present. In order to improve rotation and avoid some of these problems, many surgeons employ a modification, which borrows from principles of triangular flaps. A small back-cut just above the vermilion border of the medial lip element is filled by a small inferior triangular flap based on the lateral lip-element advancement flap. This allows for additional downward rotation and may also reduce vertical scar contracture by breaking the straight line. This simple modification has been used both with and without an apical back-cut along the medial cleft-side philtral incision. LaRossa (1995) employs such an inferior triangle and adds additional rotation using a reversed-S incision along the rotation incision of the medial lip-element philtral column to achieve an additional Rose—Thompson effect.

Fisher (2005; Figure 3d) extends the medial lip-element cleft-side philtral column incision away from the cleft margin in Rose—Thompson fashion first. It then curves superolaterally towards the cleft margin around the base of the columella. These maneuvers help preserve natural subunit boundaries allowing for rotation and medial lip lengthening at the expense of narrowing the philtrum to a degree. He too often adds a small inferior triangle just above the cutaneous roll for additional rotation and feels that this accentuates the pout of the lip. While this technique is included in the category of rotation/advancement repairs, it is clearly a hybrid of multiple principles, including triangle-flap techniques and use of geometric and curvilinear incisions to approach a vertically oriented closure. Another author (2008) describes two small
perpendicular back-cuts along the mid-portion of the rotation incision of the philtral column into which he advances two small triangles from the lateral lip-advancement flap.\textsuperscript{37} As two triangles are used, these triangles can be relatively small; however, the cost of multiple triangles is a reconstructed philtral column that is broken up in a zigzag fashion.

Yet another modification described by Song in 1998 (Figure 3e) borrows a superolateral rectangular columnar flap from the medial lip/nasal element. This is then rotated downwards filling in the rotation defect beneath the columnar base.\textsuperscript{38} Adequate rotation is achieved at the expense of borrowing nasal vestibular tissue arising lateral to the columella and transposing it into the apex of the philtrum.

Rotation/advancement techniques have been acclaimed for the ability to ‘cut as you go’ or tailor and trim flaps throughout surgery without the reliance on exact geometric measurements. This also makes these repairs more challenging to teach and learn.

Rotation/advancement repairs allow for caudal rotation of the medial lip element. The resultant rotational defect is then filled by either an appropriately sized C-flap or a correspondingly sized pennant base of the lateral lip element. This is often at the expense of the transverse width of the lateral lip element, an argument which has prompted some surgeons to include small inferiorly based triangle flaps along the lateral lip element.\textsuperscript{21,33,34}

This article reviews the evolution of unilateral cleft lip repair with special emphasis on techniques that allow for rotation and resultant increased lengthening of the medial cleft lip element. Understanding the history and principles of cleft surgery enables the surgeon to confidently evaluate form, function and aesthetics in an effort to achieve a natural-appearing functional repair, which preserves the subunits of lip and philtrum, and minimizes potential growth disturbances as well as unsightly scar and contour irregularities.

Most North American surgeons use rotation/advancement techniques in some form or fashion, and while a relatively small percentage use triangular flap repairs alone, a number who perform rotation/advancement repair also employ triangular flap principles to achieve additional rotation.\textsuperscript{3} While no technique is perfect, Millard’s rotation/advancement technique was radically innovative and numerous modifications have been proposed to address perceived shortcomings.\textsuperscript{26–28,31–34}

A review of cleft lip repair techniques is useful in evaluating underlying rotation principles which are commonly shared. It is clear that no classification system of cleft lip repair techniques is perfect. All of the above types of repairs involve rotation and advancement to one degree or another and most involve geometrically oriented flaps. In the end, designing such flaps in a way that achieves desired rotation, both vertical and horizontal lip length and minimizes disruption of natural philtral and nasal aesthetic subunits is optimal. Even if only one technique is repeatedly used, a careful review of the evolution of cleft repair is useful to evaluate the underlying principles of change which determine efficacy, thereby seeking to improve analysis and performance through refinement of personal techniques.

### Conflict of interests statement

None.

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