Cephalic Positioning of the Lateral Crura

Implications for Nasal Tip-plasty

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Objective: To apply a mathematical model to determine the relative effectiveness of various tip-plasty maneuvers while the lateral crura are in cephalic position compared with orthotopic position.

Methods: A Matlab (MathWorks, Natick, Massachusetts) computer program, called the Tip-Plasty Simulator, was developed to model the medial and lateral crura of the tripod concept in order to estimate the change in projection, rotation, and nasal length yielded by changes in crural length. The following rhinoplasty techniques were modeled in the software program: columellar strut graft/tongue-in-groove, lateral crural steal, lateral crural overlay, medial/intermediate crural overlay, hinge release with alar strut graft, and lateral crural repositioning.

Results: Using the Tip-Plasty Simulator, the directionality of the change in projection, rotation, and nasal length produced by the various tip-plasty maneuvers, as shown by our mathematical model, is largely the same as that expected and observed clinically. Notably, cephalically positioned lateral crura affected the results of the rhinoplasty maneuvers studied.

Conclusions: By demonstrating a difference in the magnitude of change resulting from various rhinoplasty maneuvers, the results of this study enhance the ability of the rhinoplasty surgeon to predict the effects of various tip-plasty maneuvers, given the variable range in alar cartilage orientation that he or she is likely to encounter.

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THE SIZE, SHAPE, AND POSItion of the lower lateral cartilages are integral to the appearance of the nasal tip. The concept of cephalically positioned lateral crura was introduced approximately 30 years ago.[1,2] While research efforts are actively devoted toward a strict definition,[3] the existing literature only indicates an approximate normal anatomical orientation for the lower lateral cartilages. Descriptions of cephalically oriented lateral crura tend to place them 30° from midline and directed toward the medial canthi. This position differs from the typical description for normally positioned ("orthotopic") lateral crura, placing them at an angle of 45° or more from midline and directed toward the lateral canthus. Although it is well accepted that the structure and position of the lower lateral cartilages are major contributors to tip dynamics, the effect of cephalic position on the form and function of the nasal tip remains a topic of debate and is often misunderstood.[4]

Cephalically positioned lateral crura have been implicated in various conditions, such as external valvular incompetence,[5,6] tip boxiness and underprojection, and the parenthesis tip deformity.[7,8] Furthermore, while an understanding of the impact of cephalic positioning on rhinoplasty outcomes is still largely unknown,[9] many believe that it can predispose patients to unfavorable results, and that it correlates with increased revision rates.[10] Indeed, cephalic positioning is becoming increasingly recognized as a distinct entity requiring particular attention; various maneuvers, such as composite grafts,[11] repositioning, or even cartilage Z-plasty,[12] are being directed specifically at correcting this abnormality.

In nasal tip-plasty, a given maneuver may produce different results in different patients. Although there are many contributing factors that affect the results of tip-refining procedures, the previously unrecognized, or underdiagnosed, condition of cephalically positioned lateral crura often may be responsible. Because of the complex 3-dimensional spatial orientation of the lower lateral cartilages within the nasal tip, it is difficult to predict the effect of cephalic position on the expected results of particular maneuvers. However, a mathematical model can pro-
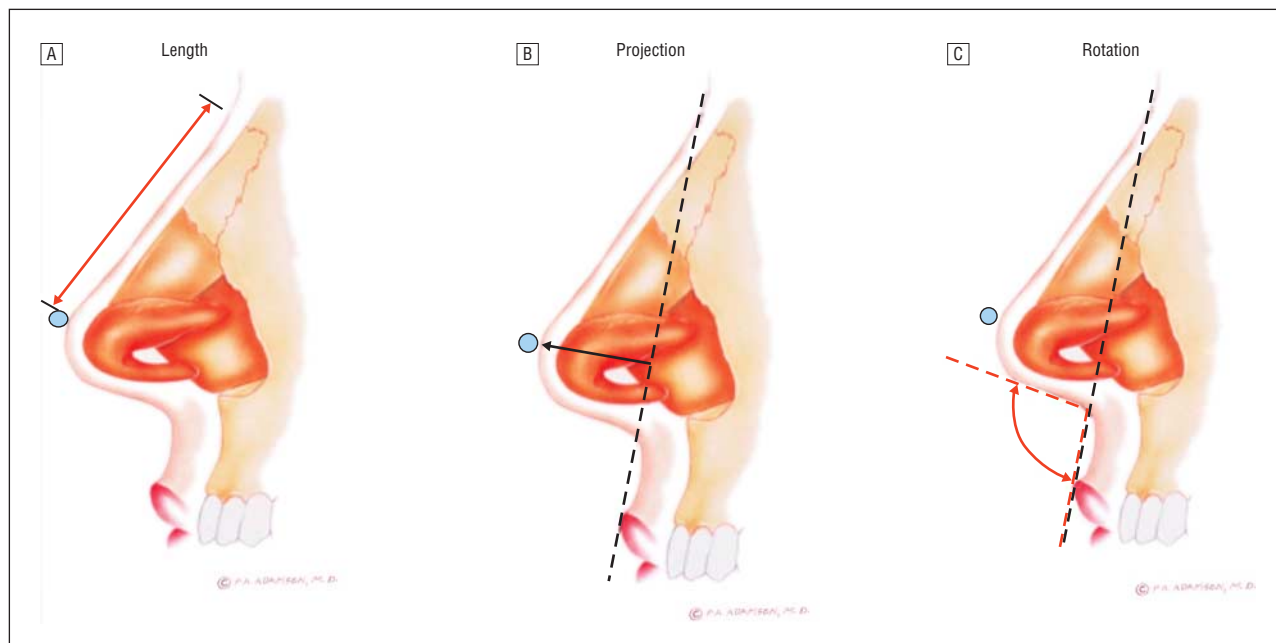
Figure 1. Definition of nasal length (A), projection (B), and rotation (C) parameters.

vide a means by which to study the effect of various lower lateral cartilage maneuvers on tip position. Furthermore, a given maneuver can be applied to the lateral crura in orthotopic position vs cephalic position, and the corresponding changes in tip position can be compared.

Currently, the M-arch model is the most sophisticated conceptual representation of the lower lateral crura and can be applied in nasal tip refinement.[13] This model incorporates the contribution of the intermediate crura to that of the medial crura within the columellar and lobular portions of the alar cartilaginous arch, and the tip-defining points (TDPs) are accurately located at the junction of the intermediate crura and the lateral crura.[14] However, in the tripod concept (on which the M-arch model is based), the TDPs are simply represented by the apex of the pyramid.[15,16] While the tripod concept is less sophisticated, the simplicity of its geometry can be useful in that the legs of the tripod can be envisioned in a variety of orientations, representing, eg, lateral crura in orthotopic position or cephalic position. Altering the lengths of the legs of the tripod to represent these 2 orientations allows comparison of the relative extent of change in projection, rotation, and nasal length.

The aim of this study was to apply a mathematical model to determine the relative effectiveness of various tip-plasty maneuvers while the lateral crura are in cephalic position, as compared with orthotopic position. Ultimately, these findings should help rhinoplasty surgeons obtain more predictable results by enhancing their understanding of nasal tip dynamics and by anticipating different magnitudes of change from various maneuvers, depending on the initial orientation of the lateral crura.

METHODS

According to the literature, the average lateral crural length is 25 mm and the average medial crural length is 20 mm.[17,18] For

our purposes, the medial crus includes the intermediate crus. No published data could be found on these measurements in cephalic vs orthotopic lateral crura. Neoclassic canons of facial beauty have defined the ideal nasolabial angle as 90° to 105° in males and 105° to 120° in females.[19] In patients presenting for rhinoplasty, this angle is likely more acute; in fact, in 1 study cohort, it was measured at 90°.[20]

A Matlab (MathWorks, Natick, Massachusetts) computer program, called the Tip-Plasty Simulator, was developed to model the medial and lateral crura of the tripod concept to estimate the change in projection, rotation, and vertical movement of the TDP yielded by changes in crural length. Projection is defined as the perpendicular distance from the anterior facial plane to the TDP. Rotation (corresponding to the nasolabial angle) is defined as the angle between the anterior facial plane and the line tangent to the columella. Nasal length is defined as the distance from the nasofrontal angle to the TDP (**Figure 1**). Vertical (ie, cephalad or caudad) movement of the TDP is directly proportional to the change in nasal length, and, for the purposes of this article, the change in this nasal parameter will be extrapolated to a change in nasal length. In the Tip-Plasty Simulator, the starting lateral crural length was defined as 25 mm, and the starting medial crural length was defined as 20 mm. The starting rotation of the medial crura was defined as 90°. Orthotopic position of the lateral crura was defined as 60° from midline in the coronal plane; intermediate position was defined as 45° from midline; and cephalic position was defined as 30° from midline (**Figure 2** and **Figure 3**). The position of the lateral crura in the axial and sagittal planes was determined by the requirement that the lateral end of the lateral crura should contact the facial plane. Therefore, the results of this study are only valid for these orientations.

The following rhinoplasty techniques were modeled in the software program: columellar strut graft/tongue-in-groove, lateral crural steal, lateral crural overlay, medial/intermediate crural overlay, hinge release with alar strut graft, and lateral crural repositioning. The definitions of these techniques are shown in **Table 1**. The specific additions or subtractions of crural length that were applied in the software program were based on both the landmark article description of each technique and the most common empirical surgical techniques of the senior author (P.A.A.).
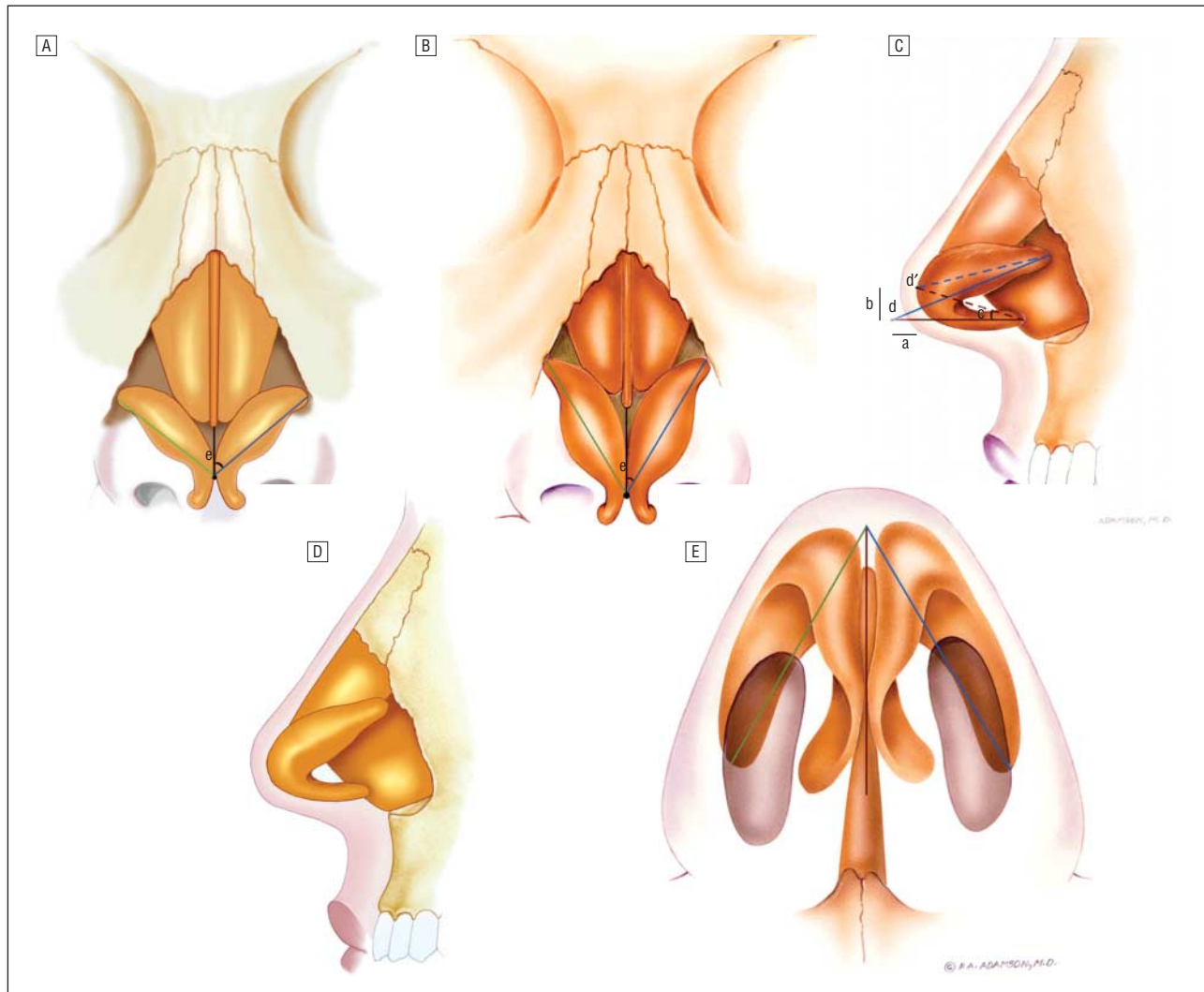
Figure 2. Adamson rhinoplasty diagram. A, Anteroposterior (frontal) view with the lateral crura in orthotopic postion. The green line indicates the vector of the right lateral crus; blue line, the vector of the left lateral crus; black line, the vertical midsagittal line; and angle e, the angle between the lateral crural vector and the midsagittal line. B, Anteroposterior (frontal) view with the lateral crura in cephalic postion. The green line indicates the vector of the right lateral crus; blue line, the vector of the left lateral crus; black line, the vertical midsagittal line; and angle e, the angle between the lateral crural vector and the midsagittal line. C, Lateral view with the lateral crura in orthotopic position. The solid blue line indicates the starting vector of the lateral crus; solid red line, the starting resultant vector of the combined medial and intermediate crural vectors; dotted blue and red lines, respective final vectors after a combination of lateral and medial/intermediate crural overlay; angle c, the change in rotation; point d, the starting location of the tip-defining point (TDP); point d', the final location of the TDP; distance a, the change in projection; and distance b, the superior/inferior movement of the TDP. D, Lateral view with the lateral crura in cephalic position. E, Basal view. The red line indicates the vector of the medial crura; green line, the vector of the right lateral crus; and blue line, the vector of the left lateral crus.

RESULTS

The effects of the various alar cartilage changing maneuvers on tip projection, rotation, and vertical movement are shown in **Table 2** for 3 anatomical situations: the lateral crura in orthotopic position, intermediate position, and cephalic position. Three maneuvers deserve special mention because their findings are not intuitive and are contrary to some conventional thinking.

For lateral crural steal, 3 mm was taken from the lateral crura (from 25 mm to 22 mm), and 3 mm was added to the medial crura (from 20 mm to 23 mm).[21] Moving the lateral crura from an orthotopic position to a cephalic position reduced the rotation and cephalic movement of the TDP achieved with this maneuver; the maneuver also went from being one that deprojected the nose to one that slightly projected the nose.
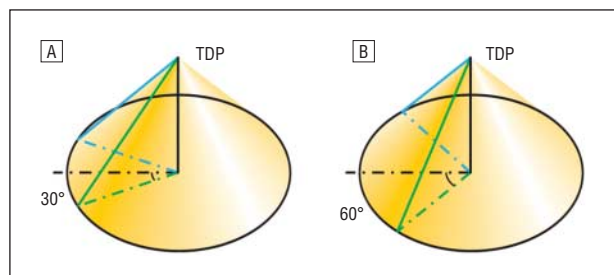

Figure 3. Illustration of the concept that repositioning the lateral crura without changing their length does not change the position of the tripod apex. The tripod concept superimposed onto a cone is seen in the surgeon's view. The lateral crura are repositioned from cephalic on the left (A) to orthotopic on the right (B), keeping their lengths constant, and the tip-defining point (TDP) remains stationary in space. The solid green and blue lines indicate the right and left lateral crura, respectively; dotted green and blue lines, their projection onto the base of the cone; black line, the combined medial crura; and dotted black line, the midsagittal line.

Maneuver/Technique	Definition
Columellar strut/tongue in groove	Used to maintain/control tip projection and rotation, both of these techniques require the creation of a pocket or space between the medial crura, which are then sutured flanking a graft or the caudal septum. If advanced anteriorly, this maneuver increases the length of the medial leg of the tripod.
Lateral crural steal	The lateral crura are advanced medially and a portion of their lengths are folded into that of the intermediate crura. Bilateral mattress sutures are placed to establish the newly created domes atop shortened lateral crura and lengthened intermediate crura.
Lateral crural overlay	After elevation of vestibular skin, the lateral crura are linearly incised from their cephalic to caudal margins (ie, perpendicular to their long axes), overlapped, and fixed with horizontal mattress sutures, thus reducing the length of the lateral legs of the tripod.
Medial/intermediate crural overlay	After elevation of vestibular skin, the medial/intermediate crura are linearly incised from their cephalic to caudal margins (ie, perpendicular to their long axes), overlapped, and fixed with horizontal mattress sutures, thus reducing the length of the medial legs of the tripod.
Medial/intermediate and lateral crural overlay	Combination of the 2 techniques as described above, thus reducing the lengths of all 3 legs of the tripod.
Hinge release with alar strut graft	After elevation of the vestibular skin, the lateral crura are released at the hinge region and advanced medially supported by alar strut grafts resting on the bony edge of the piriform aperture, thus increasing the length of the lateral legs of the tripod.
Lateral crural repositioning	After elevation of vestibular skin, the lateral crura are released at the hinge region and repositioned, usually caudally, along the bony edge of the piriform aperture, without changing the lengths of the legs of the tripod (usually done with lateral crural strut grafts)

Table 2. The Change in Tip Projection, Tip Rotation (Nasolabial Angle), and Nasal Length With Various Alar Cartilage Maneuvers With the Lateral Crura in Orthotopic, Intermediate, and Cephalic Postions[a]

Maneuver/Technique	Lateral Crural Length (Change), mm[b]	Medial Crural Length (Change), mm[c]	Change								
			In Projection, mm			In Rotation,°			In Nasal Length, mm		
			Orthotopic Position	Intermediate Position	Cephalic Postion	Orthotopic Position	Intermediate Position	Cephalic Postion	Orthotopic Position	Intermediate Position	Cephalic Postion
Columellar strut /tongue in groove	25 (0)	23 (+3)	21.33 (1.33)	22.18 (2.18)	22.45 (2.46)	111.95 (21.96)	105.33 (15.33)	102.46 (12.47)	−8.60	−6.08	−4.97
Lateral crural steal	22 (-3)	23 (+3)	14.31 (−5.68)	19.15 (−0.84)	20.51 (0.52)	141.50 (51.50)	123.59 (33.60)	116.86 (26.86)	−18.00	−12.73	−10.39
Medial/intermediate and lateral crural overlay	20 (−5)	15 (−5)	14.62 (−5.38)	14.81 (−5.19)	14.87 (−5.12)	102.83 (12.84)	99.04 (9.04)	97.37 (7.37)	−3.33	−2.35	−1.92
Lateral crural overlay	20 (−5)	20 (0)	13.22 (−6.77)	16.95 (−3.04)	18.02 (−1.97)	138.59 (48.59)	122.02 (32.03)	115.65 (25.66)	−15.00	−10.60	−8.66
Medial/intermediate crural overlay	25 (0)	15 (−5)	9.42 (−10.57)	12.52 (−7.47)	13.40 (−6.60)	38.94 (−51.06)	56.63 (−33.37)	63.31 (−26.68)	11.67	8.25	6.74
Hinge release with alar strut graft	30 (+5)	20 (0)	7.99 (−12.01)	15.22 (−4.77)	16.96 (−3.03)	23.55 (−66.44)	49.59 (−40.40)	58.04 (−31.95)	18.33	12.96	10.58
Lateral crural repositioning	25 (0)	20 (0)	20 (0)	20 (0)	20 (0)	90 (0)	90 (0)	90 (0)	0	0	0

[a] A negative change in projection represents deprojection; a negative change in rotation represents counterrotation; a negative change in nasal length represents the superior (cephalad) movement of the tip-defining point; and a positive change in nasal length represents the inferior (caudad) movement of the tip-defining point.
[b] Starting length, 25 mm.
[c] Starting length, 20 mm.

For hinge release with alar strut graft, 5 mm was added to the length of the lateral crura (from 25 mm to 30 mm) without changing the length of the medial crura. Cephalically positioned lateral crura reduced the deprojection, counterrotation, and nasal lengthening accomplished by this maneuver.

For lateral crural repositioning, the length of the lateral and medial crura was kept the same (25 mm and 20 mm, respectively). Therefore, there was no change in nasal rotation, projection, or length. This maneuver can be represented by a cone with the medial crural leg of the tripod at the center. As the lateral crura were rotated or swept along the surface of the cone, the tip of the cone remained in the same place (Figure 3).

COMMENT

Using the Tip-Plasty Simulator, we have found that cephalic position can have important and predictable effects on various tip-plasty maneuvers. The directionality of the change in projection, rotation, and nasal length produced by the various tip-plasty maneuvers, as shown by our mathematical model, is largely the same as that expected and observed clinically. The findings are confined to a specific scenario for lower lateral cartilage spatial orientation and for crural length manipulation. However, the importance of the results presented herein lies in their relative values, which serve as a theoretical foundation from which to understand and predict the out-

Table 3. Effectiveness of Various Tip-Plasty Maneuvers on Cephalically Positioned (Compared With Orthotopically Positioned) Lateral Crura, as Predicted by the Tip-Plasty Simulator[a]

Technique/ Maneuver	Projection	Rotation	Change in Nasal Length
Columellar strut/tongue in groove	Increased projection	Decreased rotation	Decreased shortening
Lateral crural steal	Convert from deprojection to projection	Decreased rotation	Decreased shortening
Medial/ intermediate and lateral crural overlay	Decreased deprojection	Decreased rotation	Decreased shortening
Lateral crural overlay	Decreased deprojection	Decreased rotation	Decreased shortening
Medial/ intermediate crural overlay	Decreased deprojection	Decreased counterrotation	Decreased lengthening
Hinge release with alar strut graft	Decreased deprojection	Decreased counterrotation	Decreased lengthening

[a]The Tip-Plasty Simulator is a Matlab computer program (MathWorks, Natick, Massachusetts).

Figure 4. How rotation affects projection. Demonstration of the decrease in projection associated with rotation or counterrotation of the nasal tip when starting at the initial nasolabial angle of 90°. All lines are the same length.

comes of particular techniques used in the setting of cephalic position.

Cephalically positioned lateral crura affect the results of the various tip-plasty maneuvers, relative to these maneuvers performed on orthotopically positioned lateral crura (**Table 3**). They diminish the degree of rotation that is obtainable with a lateral crural steal, lateral crural overlay, columellar strut graft, and combination lateral and medial/intermediate crural overlay. They also attenuate the degree of counterrotation that is obtainable with hinge release with alar strut graft and medial/ intermediate crural overlay.

Cephalically positioned lateral crura decrease the amount of nasal shortening that is obtainable with a lateral crural steal, lateral crural overlay, columellar strut graft, and combination lateral and medial/intermediate crural overlay. They also decrease the amount of nasal lengthening that is obtainable with a hinge release with alar strut graft and medial crural overlay.

Cephalically positioned lateral crura decrease the amount of deprojection that is obtainable with a medial crural overlay, hinge release with alar strut graft, lateral crural overlay, and combination lateral and medial/ intermediate crural overlay. They increase the amount of projection that is obtainable with a columellar strut or a tongue-in-groove maneuver. When the lateral crura are in orthotopic position, the lateral crural steal is a deprojecting maneuver. If the lateral crura are in an intermediate position, there is less deprojection seen, and if they are in cephalic position, a lateral crural steal slightly projects the nose.

Two results that are counterintuitive to empirical surgical observations were obtained with this mathematical model: (1) a hinge release with an alar strut graft caus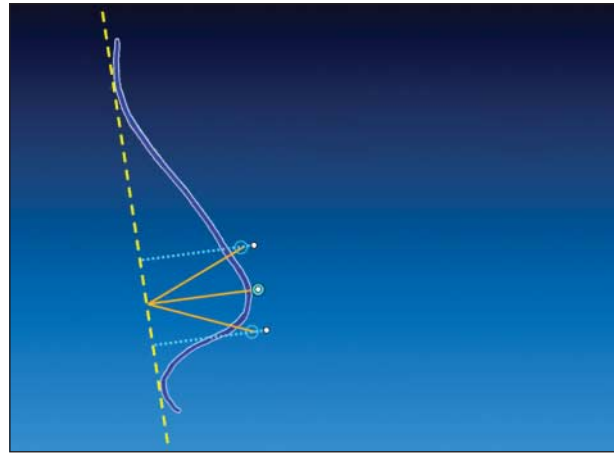ed deprojection; and (2) a lateral crural steal caused deprojection with the lateral crura in orthotopic position and projection with the lateral crura in cephalic position. These findings are geometric consequences. With the former maneuver, the projection that accompanies lateral crural lengthening is outweighed by the deprojection that is associated with the degree of counterrotation, resulting in a net deprojection. Similarly, with the latter maneuver, the projection associated with medial/intermediate crural lengthening is outweighed by the deprojection associated with the degree of rotation in the setting of orthotopic lateral crura. Therefore, the net result in that setting is deprojection (**Figure 4**). However, in the setting of cephalically positioned lateral crura, there is less rotation (and associated deprojection) with the lateral crural steal, shifting the balance to a net projection.

It should be noted that these results describe the basic geometric changes predicted by the fundamental tripod model, but the absolute values may not reflect the extent of changes expected in vivo for several reasons. First, this study was performed assuming that the length of the alar cartilage components—the medial, intermediate, and lateral crura—are the same when the lateral crura are in orthotopic position as when they are in cephalic position. This assumption would need to be further studied, as a change in the cartilaginous lengths for those 2 variants would affect the results. Moreover, any changes made to the cartilaginous framework of the nasal tip are also subject to the influence of the dynamic tension forces within the tip cartilages. In other words, the lateral crus thrusts the dome anteriorly and caudally, creating projecting, counterrotating, and nasal-lengthening forces. Furthermore, the medial crus thrusts the dome anteriorly and cephalically, creating projecting, rotating, and nasal-shortening forces. The resultant force of these apposing forces creates the ultimate position of the TDP. The skin–soft-tissue envelope mass and scar contraction forces further contribute to the ultimate nasal tip position. Finally, the tripod concept, while fundamental, does not take into account the true 3-dimensional nature of the alar cartilages. By incorporating the intermediate crura and the spring-loaded forces of the alar cartilages, the M-arch model is a more accurate representation of their 3-dimensional structural tendencies.

The results of our mathematically modeled surgical outcomes shed light on the complex interplay between cephalically oriented lateral crura and nasal tip dynamics. Furthermore, the Tip-Plasty Simulator enhances the ability of the rhinoplasty surgeon to predict the effects of various tip-plasty maneuvers, given the variable range in alar cartilage orientation that he or she is likely to encounter. Future research will prospectively correlate simulated results with actual patient outcomes to further validate the reliability of the Tip-Plasty Simulator. It is hoped that continued integration between anatomical study and computer modeling will enable further evolution of our model to aid in preoperative planning and potentially to assess other anatomical variants.

Three-dimensional computer modeling plays an important role in many facets of industry and design and is becoming increasingly valuable in facial aesthetic and reconstructive surgery. Building on the concepts highlighted in this article, future computerized modeling systems may prove to be pivotal to optimize preoperative planning for rhinoplasty patients.

In conclusion, every stage of rhinoplasty—preoperative analysis, intraoperative technical maneuvers, and postoperative course of healing—influences the final surgical outcome. The relationship between anatomical variation and tip dynamics is complex. The results of this study demonstrate that cephalically positioned lateral crura can affect the results of various tip-plasty maneuvers, at least as measured geometrically. Fortunately, the relative effect of cephalically positioned lateral crura on these maneuvers can be predicted. It is recognized that in vivo factors will influence these geometrically determined changes, but if this effect is taken into account during the preoperative planning and intraoperative execution of tip-plasty maneuvers, the rhinoplasty surgeon can obtain more consistent results, increasing the likelihood of postoperative success and patient satisfaction.

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