Original Article

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The Effects of Nasoalveolar Molding on Nasal Proportions at the Time of Nasal Maturity

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Abstract

Background: The aim of this study is to assess the effect of nasoalveolar molding (NAM) versus no-NAM on nasal morphology in patients with unilateral cleft lip and palate (UCLP) at the time of nasal maturity.

Methods: A retrospective, single-institution review was conducted on all non-syndromic patients with UCLP. Inclusion criteria included age 14 years or above, unilateral cleft repair at the time of infancy, and adequate photography taken at nasal maturity and prior to rhinoplasty. Exclusion criteria included age less than 14 years, syndromic diagnosis, and rhinoplasty prior to nasal maturity. Ten parameters were measured twice from standardized clinical photographs using the Dolphin Imaging Software for establishment of intrarater reliability. Subjective analysis was achieved through completion of the Asher McDade grading scale by 3 expert cleft practitioners.

Results: Nostril height, columellar angle, alar cant, vertical alar height, alar height angle, nasofacial angle, and nasolabial angle were found to be significantly less severe in patients who had undergone NAM in conjunction with surgical repair when compared with those who had undergone surgical repair alone. Asher McDade grading revealed significant improvement in nasal form, nasal symmetry/deviation, nasal profile, vermillion border, and overall score in patients who underwent NAM compared to no-NAM.

Conclusion: The use of presurgical NAM during infancy can improve nasal symmetry and nasal proportions at the time of nasal maturity.

Keywords

craniofacial growth, craniofacial morphology, facial growth, midfacial growth, nasal morphology, nose

Introduction

Nasoalveolar molding (NAM), a form of presurgical infant orthopedics, was first described as a method of preoperative columellar lengthening and premaxillary repositioning in patients with complete bilateral cleft lip and palate (Grayson et al., 1993). It employs an acrylic oral molding plate and nasal footplates which are gradually modified over time to preoperatively improve nasal shape and symmetry, restore the anatomic position of the alveolus, and decrease the width of the cleft (Grayson et al., 1999) by capitalizing on the malleability of cartilage unique to the first 6 weeks of life. Concepts of tissue expansion are also employed in lengthening of the columella and prolabium via principles of traction and counter-traction exerted through the NAM device (Grayson et al., 1993, Grayson et al., 1999). Currently, NAM is a commonly implemented form of passive presurgical infant orthopedics by over one-third of cleft centers accredited by the American Cleft Palate-Craniofacial Association (Sischo et al., 2012).

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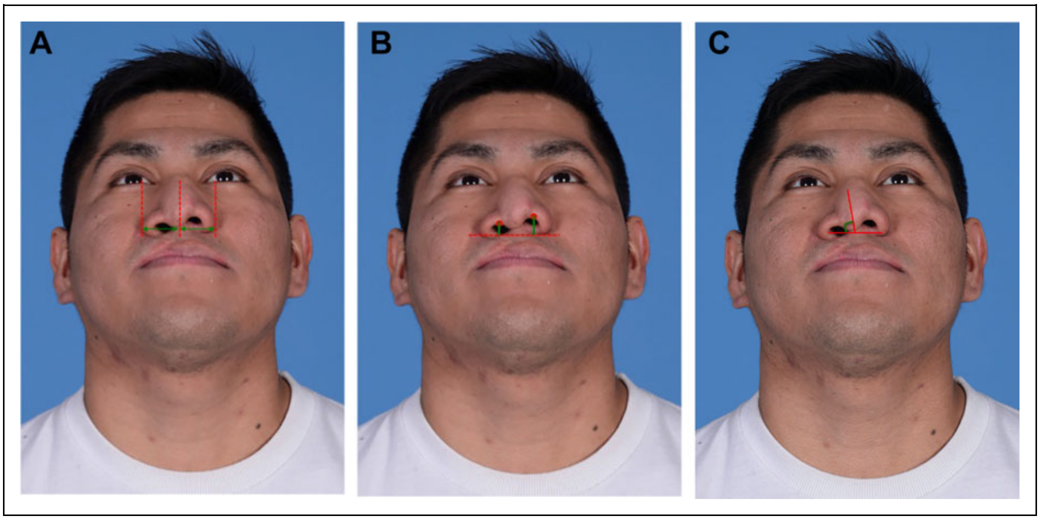

Figure 1. A, Worm's eye view photographs depicting alar base width, (B) nostril height, and (C) columellar angle.

Surgeons treating patients with unilateral cleft lip and nasal deformities are tasked with restoring facial form and function with the least amount of surgical intervention. Indeed, patients with a cleft who undergo NAM intervention demonstrate greater nasal symmetry at the age of mixed dentition (Barillas et al., 2009) require less secondary rhinoplasty prior to the age of facial maturity (Patel et al., 2015) and are felt to have greater positive change to appearance by both their caregivers and by expert surgeon analysis (Broder et al., 2016). Furthermore, presurgical assessment of patients with a cleft demonstrates that patients who have completed NAM (compared to those who did not undergo NAM) were rated by surgeons to have a less severe cleft, would have the better surgical outcome, and would need less revision surgery (Rubin et al., 2015).

Although there are several studies that demonstrate the benefits of NAM to nasal form, including recent additions to the literature (Liang et al., 2018), none have reported the final assessment at the time of nasal maturity. The aim of this study is to assess the effect of NAM versus no-NAM on nasal morphology measurements on a population of nonsyndromic patients with unilateral cleft lip and palate (UCLP) at the time of nasal maturity.

Methods

Institutional review board approval was obtained prior to the start of this study. A retrospective, single-institution review was conducted on all nonsyndromic patients with UCLP with clinical records available at or past the age of nasal maturity, defined as 14 years of age (van der Heijden et al., 2008). Patients were included in the study if they were aged 14 years or older, had unilateral cleft repair at the time of infancy, and had adequate photography taken at or past the age of nasal maturity and prior to definitive rhinoplasty. Patients were excluded if they were syndromic, had incomplete clinical recorders, were younger than 14 years, or had been documented as having undergone rhinoplasty or surgical manipulation of the nose between the time of initial lip repair and time of nasal maturity. All photos utilized in the study were taken prior to any form of orthognathic surgery.

Patients in the NAM group underwent cleft lip repair with primary rhinoplasty by 2 surgeons using the modified Millard's type rotational and advancement cleft lip repair technique. Patients in the non-NAM cohort had cleft lip repairs performed at several different institutions, precluding the identification of primary cleft lip and nasal repair techniques.

Objective Analysis

Ten parameters were measured: alar base width, nostril height, columellar angle, nasal tip deviation, cupid's bow deviation, alar cant, nasolabial angle, nasofacial angle, vertical alar height, and alar height angle. No absolute values were used, as alar base width, nostril height, and vertical alar height were compared as ratios of the patient's affected to the unaffected side. All other parameters listed were measured as angles. All measurements were completed on Dolphin Imaging and Management Software (2018 Patterson Dental Supply, Inc.). Alar width, nostril height, and columellar angle were measured using a worm's eye view photo. Nasofacial and nasolabial angles were measured using a sagittal photo. Nasal tip deviation, cupid's bow deviation, alar cant, vertical alar height, and alar height angle were measured using a frontal view photo. Measurements were repeated twice by the same blinded rater for the establishment of intrarater reliability.

Worm's eye view measurements. Alar width was measured as the distance between the subnasale and the lateral-most portion of the ala (Flores et al., 2009; Figure 1A). Nostril height was measured by the perpendicular distance between a horizontal line passing through the subnasale and the midpoint of the superior-most portion of each nostril (Basta et al., 2014; Figure 1B). Both alar base widths and nostril heights were then used to calculate ratios of affected to unaffected nostril to obtain a value that was

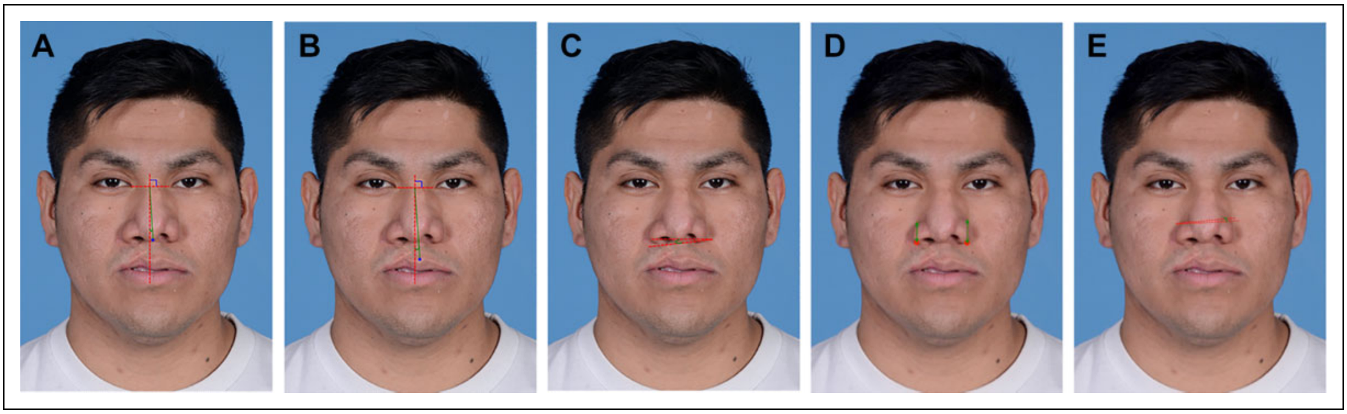

Figure 2. A, Frontal view photographs depicting nasal tip deviation, (B) cupid's bow deviation, (C) alar cant, (D) vertical alar height, and (E) alar height angle.

then compared to an absolute value of 1. Columellar angle was measured by drawing a line parallel to the medial canthi and allowing it to intersect with a line drawn parallel to the columella (Fisher et al., 2008; Figure 1C). These angles were analyzed as a function of their deviation from a 90° angle.

Frontal view *measurements.* For measurement of both nasal tip deviation (Figure 2A) and cupid's bow deviation (Figure 2B), a line was drawn connecting the medial canthi. Another bisecting line was then drawn directly perpendicular to this line. Two points were both placed at the nasal tip and the cupid's bow, respectively. Two angles connecting these points to the line drawn perpendicular to the plane of the medial canthi were then created, resulting in 2 distinct values. For measurement of the alar cant, a line was first drawn connecting the lowest points of the lateral-most portion of each nostril (Figure 2C). This line was then transposed to the line originally drawn to connect the medial canthi, and the angle formed between these 2 was measured.

Vertical alar height was measured by choosing points at the lateral base of each ala (Figure 2D). A vertical line was then drawn upward from this point to the nasal fold and measured on each side. Alar height angle was measured by drawing one horizontal line connecting the lateral ala, another connecting the nasal folds, and transposing these 2 horizontal lines for measurement of the angle created between them (Figure 2E).

Sagittal view measurements. For measurement of the nasofacial angle, Frankfurt's horizontal was first drawn. Although Frankfurt's plane is a cephalometric measurement connecting the inferior-most portion of the orbit with the porion, we approximated soft tissue landmarks in their place (inferior portion of the orbit connected to a point just above the tragus of the ear). A line was then drawn perpendicularly to Frankfurt's horizontal, and the angle created between the bridge of the nose and this orthogonal line was measured (Figure 3A). The nasolabial angle was measured by selecting 3 points (nasal tip, base of the columella, and cupid's bow) and connecting them to form an angle (Figure 3B).

All measurements are summarized in Table 1.

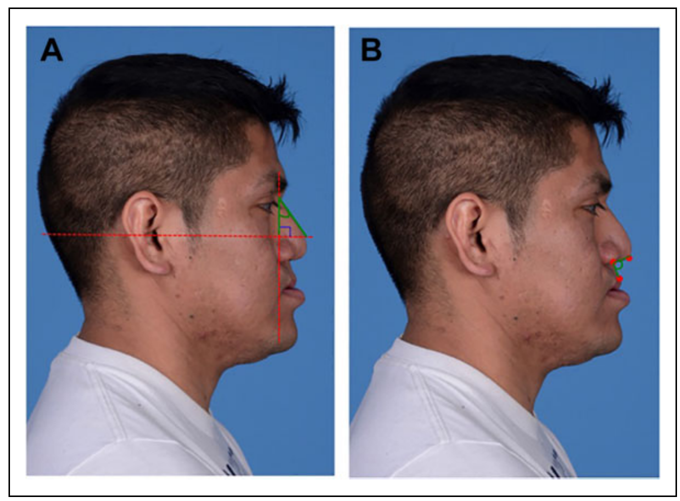

Figure 3. A, Sagittal view photographs depicting nasofacial angle and (B) nasolabial angle.

Subjective Analysis

We performed a subjective analysis in which 3 blinded cleft practitioners (2 craniofacial surgeons and 1 craniofacial orthodontist) were asked to rate patient photos using the Asher McDade rating scale. The subjective reviewers, although from the same institution where this study was conducted, were blinded and had not operated on any of the patients included in the study. Analysis of interrater reliability for each individual score (nasal form, nasal symmetry/deviation, nasal profile, and vermillion border) as well as overall Asher McDade score was obtained.

Statistical analysis. Continuous variables are reported as "mean ± SD." Data were analyzed and compared between patients who underwent NAM and those who did not. The mean values for alar base width ratio of affected to unaffected to non-affected side, nostril height ratio of affected to unaffected side, columellar angle, nasal tip deviation, cupid's bow deviation, alar cant, vertical nostril height ratio of affected to unaffected side, nostril height angle, nasofacial angle, and nasolabial angle were

Table 1. Description of Photo Measurements.

Parameter	Definition
Worm's eye view measurements	
Alar base width	Distance between the subnasale and the lateral-most portion of the ala
Nostril height	Distance between horizontal line passing through the subnasale and the midpoint of the superior-most portion of each nostril
Columellar angle	Angle formed between line through medial canthi and line parallel to the columella
Frontal view measurements	
Nasal tip deviation	Angle formed between a line perpendicular to a plane through the medial canthi and a line drawn from the nasal tip to a midpoint between the medial canthi
Cupid's bow deviation	Angle formed between a line perpendicular to a plane through the medial canthi and a line drawn from the cupid's bow to a midpoint between the medial canthi
Alar cant	Angle between a line through the lowest points of the lateral-most portion of each nostril and a line connecting the medial canthi
Vertical alar height	Distance between the lateral base of each ala and the nasal fold
Alar height angle	Angle formed between a line connecting the lateral ala and a line connecting nasal folds
Sagittal view measurements	
Nasofacial angle	Angle formed between a line perpendicular to Frankfurt's horizontal and a line along the bridge of the nose
Nasolabial angle	Angle formed between three points (nasal tip, base of the columella, and cupid's bow)

calculated and compared between groups. A Student t test was used for comparison of means between groups and statistical significance was reached if $P < .05$. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS, IBM Corp. v23).

Results

Objective Analysis Results

A total of 92 unilateral, complete cleft patients at the age of nasal maturity were initially identified. However, only 41 of these patients were non-syndromic patients with UCLP who met the inclusion criteria. Twenty unilateral cleft lip patients underwent NAM during the time of infancy (mean age = 23 ± 1.93; age range 18-25; 10 male, 10 female) and 21 did not (mean age = 22 ± 4.7; age range 17-29; 16 male, 5 female). Within the NAM group and non-NAM groups, 16 and 15 patients were characterized as having complete clefts, respectively. Additionally, 11 NAM patients and 9 non-NAM patients were treated with alveolar bone graft (ABG) following initial repair. None of the NAM group patients underwent bone graft augmentation to the bony perialar base. Intrarater reliability was rated as excellent (>0.9) for all parameters except nasofacial angle which was rated as good (0.887).

Table 2. Values of Photographic Measurements. NAM vs Non-NAM.

Parameter	NAM group	Non-NAM group	*P* value
Worm's eye view measurements			
Alar base width	0.99 ± 0.08	1.04 ± 0.13	.115
Columellar height	0.88 ± 0.09	0.73 ± 0.17	.002
Columellar angle	3.55 ± 2.64	9.61 ± 7.17	.001
Frontal view measurements			
Nasal tip deviation	2.43 ± 1.48	2.54 ± 1.76	.833
Cupid's bow deviation	2.68 ± 1.24	2.12 ± 0.86	.098
Alar cant	2.57 ± 2.54	4.50 ± 2.99	.032
Vertical alar height	0.92 ± 0.10	0.83 ± 0.08	.005
Alar height angle	3.70 ± 2.39	5.54 ± 2.85	.032
Sagittal view measurements			
Nasofacial angle	21.72 ± 5.29	26.43 ± 5.65	.009
Nasolabial angle	87.82 ± 10.91	68.17 ± 17.43	.001

Abbreviation: NAM, nasoalveolar molding.

Worm's eye view measurements. Alar base width ratio did not significantly differ between the NAM and non-NAM groups (0.99 ± 0.08 vs 1.04 ± 0.13; $P = .115$). Nostril height ratio was significantly greater in NAM patients than in non-NAM patients (0.88 ± 0.09 vs 0.73 ± 0.17; $P = .002$). Columellar angle, measured as a difference from 90°, was significantly greater in NAM patients when compared to non-NAM patients (86.45 [difference of 3.55 ± 2.64] vs 80.39 [difference of 9.61 ± 7.17]; $P = .001$).

Frontal view measurements. Nasal tip deviation did not significantly vary between the NAM and non-NAM groups (2.43 ± 1.48 vs 2.54 ± 1.76; $P = .833$). Cupid's bow deviation similarly did not significantly vary between the NAM and non-NAM groups (2.68 ± 1.24 vs 2.12 ± 0.86; $P = .098$). Alar cant, however, was significantly less severe in NAM patients when compared to patients who did not undergo NAM (2.57 ± 2.54 vs 4.50 ± 2.99; $P = .032$). Vertical alar height ratio was also found to be significantly different between the NAM and non-NAM groups (0.92 ± 0.10 vs 0.83 ± 0.08; $P = .005$). Lastly, alar height angle was significantly less severe in NAM patients than in non-NAM patients (3.70 ± 2.39 vs 5.54 ± 2.85; $P = .032$).

Sagittal view measurements. The nasofacial angle significantly differed between NAM and non-NAM groups (21.72 ± 5.29 vs 26.43 ± 5.65; $P = .009$). The nasolabial angle was also significantly different between NAM and non-NAM groups (87.82 ± 10.91 vs 68.17 ± 17.43; $P < .001$). Objective analysis results are summarized in Table 2.

Subjective Analysis Results

Analysis of interrater reliability for each individual score (nasal form, nasal symmetry/deviation, nasal profile, and vermillion border) as well as overall Asher. McDade score demonstrated appropriate consistency and was rated as good between all raters (0.7-0.9). Analysis of NAM vs no-NAM groups revealed that patients who underwent NAM had significantly less severe Asher McDade scores for nasal form (2.02 vs 3.03, $P = .001$), nasal symmetry/deviation (2.1 vs 3.03, $P = .001$), nasal profile (2.12 vs 2.92, $P = .001$), vermillion border (1.63 vs 2.70, $P < .001$), and overall score (1.97 vs 2.92, $P < .001$).

Discussion

Infants affected by complete UCLP present with unique nasal deformities which include: nasal tip deviation, inferior rotation of the lower lateral cartilage on the cleft side, vertical shortening of the columella on the cleft side, displacement of the columellar base toward the non-cleft side, lateralization of the alar base on the cleft side, and inferior displacement of the nostril apex on the cleft side (Grayson and Garfinkle, 2014). The cleft surgeon and team, in turn, are tasked with restoring facial, symmetry, form and function with, ideally, limited surgical intervention, and exposure to anesthesia. In order to best achieve these goals, NAM capitalizes on cartilage plasticity unique to the time of infancy to mold the lower lateral cartilage to a more symmetric shape and position, medialize the alar base, straighten and lengthen the columella, and expand the nasal lining and align the alveolar segments (Grayson and Garfinkle, 2009).

The supportive evidence for the benefit of NAM to nasal form and quality of life is diverse and include single-institution, multi-institutional retrospective and prospective multi-institutional studies. A retrospective cohort study of 25 non-syndromic patients with complete UCLP demonstrated that NAM significantly improves long-term nasal symmetry (average follow-up was 9 years; Barillas et al., 2009). In a study that sought to assess the changes of nasal symmetry and growth following presurgical NAM and primary cheiloplasty in 25 patients with complete UCLP patients, the authors discovered that nasal symmetry was significantly improved following the use of NAM. Although there has been found to be a trend toward recurrence of nasal asymmetry in the first year following surgery due to differential growth of cleft and non-cleft sides, the authors conclude that NAM may be utilized to combat this phenomenon through preoperative narrowing of the alveolar cleft as much as possible, overcorrecting nasal vertical dimensions intraoperatively, and using a nasal conformer to maintain surgical outcomes (Liou et al., 2004).

Although the presented study was conducted in patients with UCLP, similar results have been demonstrated in patients with bilateral cleft lip and palate (BCLP). A retrospective review of 26 patients with BCLP, 13 of which underwent NAM and 13 of which underwent cleft lip and nasal repair with banked fork flaps demonstrated that NAM followed by surgical repair restored columellar length to normal by the age of 3 and significantly reduced the need for secondary nasal surgery (Lee et al., 2008). Another similarly modeled retrospective study assessed nasal morphology of patients with BCLP through the age of 12.5 years. Nasal tip projection, alar width, alar base width, columella length, and columella width were measured in 77 non-syndromic patients with bilateral cleft lip-cleft palate. Nasal morphology following NAM and surgical repair was comparable to the non-cleft control group (Garfinkle et al., 2011).

A National Institutes of Health–sponsored, prospective multicenter study asked both clinicians and caregivers to rate pre- and postoperative photographs of patients with cleft lip and palate (mean age: 13 months) who had either undergone NAM or surgery alone. Expert clinicians reported greater nasal improvement in NAM-treated infants. Patient caregivers rated the NAM patients as having had significantly better postoperative outcomes than those who underwent surgery alone, especially with regard to the nose (Broder et al., 2016). This suggests that, irrespective of precise anthropometric measurements, the overall nasal morphology may be better preserved in patients who receive NAM treatment prior to surgery.

The presented study is consistent with prior research from multiple institutions which demonstrate a benefit of NAM to nasal form in patients affected by cleft lip and palate. All previous studies, however, reported outcomes on growing children, preventing a definite conclusion to be made on the final outcome of NAM. This study is the first to assess nasal symmetry and form in response to NAM at the time of nasal maturity. We demonstrate statistically significant improvement in nostril height, columellar angle, alar cant, vertical nostril height, vertical nostril angle, nasofacial angle, and nasolabial angle in patients treated with NAM compared to those who did not undergo NAM. It is notable that both nostril width ratio and columellar angle was found to be statistically correlated with the severity of the cleft nasal deformity (Fisher et al., 2008). Furthermore, Asher McDade grading by 3 blinded cleft surgeons demonstrated improved aesthetic results in patients who underwent NAM. This reported improvements in nasal form may have positive effects on quality of life, psychosocial development, and will likely lead to a decrease in the need for revision surgery as well as the complexity of rhinoplasty required at the time of facial maturity.

Our study is not without limitations. First and foremost, our sample size is small, but this is the cost of following a patient's trajectory from the time of birth to facial maturity. Second, these measurements, although performed using computer software, are subject to human error as well. Additionally, as no 2 patients are the same, patient-specific craniofacial factors such as the extent and laterality of clefting as well as grade of malocclusion may have affected our measurements. The latter, which may be improved in the NAM population when compared to the non-NAM population, has the potential to be a limitation and would be an interesting topic for a future study. Although the photographs included in this study were taken by a professional medical photographer, it is possible that slight deviations in the frontal and worm's eye views may have impacted the accuracy of measurements taken in these views. Moreover, the photographs included were all taken at the time of skeletal maturity, thereby foregoing analysis at other time points such as birth, pre-NAM, post-NAM, post-surgery, and so on. Additionally, our NAM and non-NAM patients were operated on by different surgeons. Thus, this study does not control for surgical technique that was variable across the study groups and may be a contributor to the presented findings. Although this study does find a significant improvement in nasal form following NAM at the time of facial maturity, we cannot comment on potential additional burden of care, cost of care, or psychosocial effects of this treatment program.

Conclusion

The use of NAM during infancy in patients with a unilateral cleft lip improves nasal symmetry and nasal proportions at the time of nasal maturity compared to patients who do not undergo presurgical orthopedics.

Declaration of Conflicting Interests

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