ORIGINAL ARTICLE

Influence of preoperative velar closing ratio and lateral wall movement on outcomes of Furlow palatoplasty for velopharyngeal incompetence

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Currently, there is no consensus regarding how to determine the optimal surgical procedure for a patient with velopharyngeal incompetence (VPI) post-primary palate repair. The purpose of the present study was to assess the effect of preoperative velar closing ratio (VCR) and lateral wall movement (LWM) on nasal emission and hypernasality after Furlow double-opposing Z-plasty. A retrospective analysis involving patients with VPI post-primary palatoplasty whose VPI was treated with double-opposing Z-plasty by a single surgeon was performed. Ten consecutive patients with VPI postpalatoplasty were reviewed. Videonasendoscopy, videofluoroscopy and perceptual speech examinations were performed preoperatively and postoperatively. VCR improved from an mean of 0.5 preoperatively (range 0.1 to 0.95) to 0.9 postoperatively (range 0.55 to 1.0). Postoperative mean LWM was 0.5 (range 0.3 to 0.9), unchanged from preoperative ratings. A trend toward an inverse relationship between preoperative VCR and improvement in hypernasality and resolution of nasal emission was observed. No relationship was noted between the degree of preoperative LWM and mean improvement in hypernasality. However, patients with worse preoperative LWM experienced better resolution of nasal emission postoperatively.

Key Words: *Furlow double-opposing Z-plasty; Lateral wall movement; Velar closing ratio; Velopharyngeal insufficiency*

L'influence du ratio de fermeture vélaire et du mouvement des parois latérales préopératoires sur les résultats de la palatoplastie selon Furlow pour corriger l'insuffisance vélopharyngée

Il n'y a pas de consensus pour déterminer l'intervention chirurgicale optimale chez un patient présentant une insuffisance vélopharyngée (IVP) après une réparation palatine primaire. La présente étude visait à évaluer l'effet du ratio de fermeture vélaire (RFV) et de mouvement des parois latérales (MPL) sur l'émission nasale et l'hypernasalité après une plastie en Z en double opposition selon Furlow. Les chercheurs ont procédé à une analyse rétrospective de patients qui avaient subi une palatoplastie primaire et qui présentaient une IVP traitée par un chirurgien par une plastie en Z en double opposition. Ils ont examiné dix patients consécutifs ayant une IVP après leur palatoplastie. Ils ont effectué une vidéo-endoscopie nasale, une vidéo-fluoroscopie et des examens orthophoniques perceptuels avant et après l'opération. Le RFV s'est amélioré d'une moyenne de 0,5 avant l'opération (plage de 0,1 à 0,95) à une moyenne de 0,9 après l'opération (plage de 0,55 à 1,0). Le MPL moyen après l'opération était de 0,5 (plage de 0,3 à 0,9), identique aux mesures préopératoires. Les chercheurs ont observé une tendance inversement proportionnelle entre le RFV préopératoire, l'amélioration de la nasalité et la résolution de l'émission nasale. Ils n'ont pas remarqué de relation entre le degré préopératoire de MPL et l'amélioration moyenne de l'hypernasalité. Cependant, les patients dont le MPL était plus prononcé avant l'opération présentaient une meilleure résolution de l'émission nasale après l'opération.

Velopharyngeal insufficiency (VPI) is a problem in 15% to 25% of children with previously repaired cleft palates (CPs) (1,2). Currently, there is no consensus on the optimal surgical solution. The pharyngeal flap, sphincter pharyngoplasty and palatal lengthening procedures, including double-opposing Z-plasty, have all been used successfully in isolation and in combination. Although several studies have begun to correlate preoperative patient characteristics with surgical outcome, the choice of procedure is often based on surgeon preference, with some consideration given to the function and anatomy of the palate. Currently, adequate evidence-based criteria do not exist to delineate the most beneficial procedure for the individual patient.

The current literature regarding appropriate anatomical parameters varies greatly. Previous studies have reported that pharyngeal anterior-to-posterior (AP) distance or 'gap size' serves as the best determinant for procedure choice, while others argue that the velar closing ratio (VCR) is more important because it emphasizes the dynamics of the palate. Chen et al (3) examined both forms of measurement in a study involving 18 patients with postpalatoplasty VPI and found that double-opposing Z-plasty had the most success in alleviating VPI in patients with a 'gap size' <5 mm, and hypothesized that the maximum gap size appropriate for double-opposing Z-plasty is between 5 mm and 10 mm. In terms of velar displacement, Chen et al (3) reported their best results in alleviating VPI in patients with VCR >75%. Perkins et al (4) also extensively studied gap size as an indicator of surgical success. They had a large sample size (n=154) that consisted of both submucous and repaired CPs, and evaluated VCRs. While all of the patients within the study had preoperative sagittally oriented levator veli palatini muscles, they found that patients with VCR >80% had better results after double-opposing Z-plasty than patients with adynamic gaps (<50% closure). Perkins et al (4) also found that there was no significant difference in speech outcomes in overt versus submucous CPs when controlling for confounding factors.

Others correlate lateral wall movement (LWM) with surgical success. Chen et al (3) found that preoperative LWM >0.375 mm was an independent indicator of surgical success; however, they did not correlate this with resting port width nor investigate VCR. Gossain et al (5) stated that gap size and LWM should be considered concurrently to determine the appropriate procedure. Their study included 13 patients: 11 were postpalatoplasty and two were submucous CPs. Their findings suggest that gap sizes >7 mm with coexisting poor LWM (defined as <3 on a 1 to 5 scale) require both double-opposing Z-plasty and sphincter pharyngoplasty for surgical success. However, the authors agree with Chen et al (3) that larger gaps with good LWM may be adequately treated with double-opposing Z-plasty alone (5).

While many studies have reported that poor LWM is associated with poor surgical outcomes with double-opposing Z-plasty, those studies focused on absolute measurements of LWM and AP diameter (3,5). To our knowledge, no study has previously investigated LWM as a fraction of approximation to the midline in conjunction with VCRs. To further delineate the most beneficial procedure to correct VPI in postpalatoplasty patients, we attempted to correlate surgical success with preoperative LWM and VCRs in patients who have undergone VPI treatment with double-opposing Z-plasty.

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TABLE 1
Pre- versus postoperative measurements after Furlow palatoplasty

			Preoperative				Postoperative			
Patient	Age, years	Diagnosis	VCR	LWM	NE	HN	VCR	LWM	NE	HN
1	6.6	Cleft palate	0.80	N/A	1	2.5	0.95	0.45	0	0
2	4.1	Unilateral cleft lip and palate	0.20	0.60	1	4	0.98	0.60	0	0.5
3	5.2	Unilateral cleft lip and palate	0.25	0.50	1	3	1.00	0.60	1	1
4	7.0	Bilateral cleft lip and palate	0.40	0.40	1	3	0.95	0.90	0	1
5	4.2	Cleft palate	0.70	0.65	0	2.5	0.90	0.40	1	1
6	3.3	Unilateral cleft lip and palate	0.15	0.20	1	4	0.75	0.30	0	3.5
7	5.1	Cleft palate	0.10	0.25	1	4	0.55	0.35	0	1
8	8.6	Bilateral cleft lip and palate	0.85	0.50	0	4	1.00	0.60	1	2
9	7.9	Cleft palate	0.40	0.40	1	3	1.00	0.20	1	2
10	10.2	Cleft palate	0.80	0.50	1	2.5	0.90	0.30	1	2.5

HN Hypernasality; LWM Lateral wall movement; N/A Not applicable (examination was limited); NE Nasal emission; VCR Velar closing ratio

METHODS

A retrospective study involving 17 consecutive patients undergoing double-opposing Z-plasty for VPI postpalatoplasty was performed. Institutional review board approval was obtained. All patients met the following inclusion criteria: subjects had VPI; subjects previously underwent palatoplasty for a cleft of the secondary palate; and subjects were already followed in the craniofacial anomalies clinic. Seven patients were excluded for significant intellectual disability or other developmental delay severely impairing their speech, leaving 10 patients to be included in the present study.

A standardized protocol for perceptual speech evaluation, videonasendoscopy (VNE) and videofluroroscopy (VF) was used. Pre- and postoperative evaluations by a speech-language pathologist were reviewed, as were the outcomes of pre- and postoperative VNE and multiview VF on each patient. VNE and VF were performed by the same surgeon (ARM) in conjunction with a single speech pathologist (GR).

Perceptual speech assessment included rating of nasal emission and hypernasality. Contexts used for assessment included counting, phonetically balanced sentences and conversation. Grading was based on each patient's best performance. Nasal emission was delineated by phoneme and rated as either present or not present. Hypernasality was rated on a four-point scale with respect both to severity and consistency.

The measurements obtained through VNE and VF were based on recommendations of the International Working Group (6). On VNE, VCR measured the maximal velar excursion as a percentage or ratio of the distance from the resting velum to the posterior pharyngeal wall. LWM was measured from 0.0 to 0.5 for each lateral wall, with 0.5 denoting movement to the midline. The LWM was recorded as total LWM, whereby contact in the midline would be denoted by a combined score of 1.0. On VF, velar excursion was studied on lateral views. VCR was measured as described above. LWM was noted on basal views and measured as described above for VNE examinations.

The double-opposing Z-plasties were performed in a standardized fashion as described by Furlow (7). All were performed or supervised directly by a single surgeon (ARM) (7).

Patients were advised to discontinue speech therapy until their first follow-up examination (three to six months postoperatively) when new therapy recommendations could be made. At that time, measurements taken preoperatively were repeated.

RESULTS

The mean age at the time of surgery was 6.2 years (range three to 10 years). The mean time of postoperative measurements was 6.8 months with follow-up extending well beyond that time. Three patients had a diagnosis of unilateral cleft lip and palate (UCLP), two had bilateral cleft lip and palate and five had isolated CPs (Table 1). There were no fistulas or other postoperative complications.

Preoperative mean VCR was 0.5 (range 0.1 to 0.95). Mean LWM was 0.50 (range 0.2 to 0.65). Perceptual speech assessment exhibited an average hypernasality score of 3.3 (0 = none, 4 = severe) and eight of 10 patients had nasal emission before double-opposing Z-plasty. Two subjects had sagittally oriented levators, defined as the presence of a dorsal groove on VNE.

Postoperatively, VCR improved to a mean of 0.90 (range 0.55 to 1.0). Only two subjects did not achieve a postoperative VCR >0.8, and these subjects had the worst preoperative VCR ratings (0.1 and 0.15). The two subjects with sagittally oriented levators had poor preoperative VCRs (0.2 and 0.4) and exhibited nearly complete velar closure postoperatively (0.98 and 1.0, respectively). A trend of an inverse relationship between preoperative VCR and change in hypernasality was observed (eg, the patients with the worst preoperative VCR had the greatest improvement in hypernasality) (Table 2): patients with a preoperative VCR <0.33 had a mean improvement of 2.3 points in their hypernasality score, while those with a preoperative VCR >0.66 had an average improvement of 1.5 points in their hypernasality score. Average postoperative LWM was 0.5 (range 0.3 to 0.9), unchanged from preoperative ratings. No relationship was noted between the degree of preoperative LWM and average improvement in hypernasality (Table 3).

Nasal emissions were exhibited in five patients postoperatively. Patients with the worst preoperative VCR demonstrated the best resolution of nasal emissions postoperatively (Table 4): among patients with a preoperative VCR <0.33, 80% (four of five) demonstrated resolution of nasal emissions postoperatively; however, among patients with a preoperative VCR >0.66, none (zero of three) demonstrated resolution of nasal emissions postoperatively. Similarly, patients with the worst preoperative LWM demonstrated the best resolution of nasal emissions postoperatively (Table 5): among patients with a preoperative LWM <0.25, 100% (three of three) demonstrated resolution of nasal emissions postoperatively; however, among patients with a preoperative LWM >0.50, none (zero of two) demonstrated resolution of nasal emissions.

DISCUSSION

Double-opposing Z-plasty remains an effective tool in selected patients with VPI postprimary palatoplasty. We agree with Furlow (7) that VCR is a superior measurement to AP 'gap size' because VCR incorporates the dynamics of the palate as well as the size of the patient (8). Previous studies that focused on resting AP gap cannot be easily applied to the general population because the same gap size will have a vastly different impact on patients at different stages of development. For example, a pharyngeal AP distance of 7 mm can have very different implications in a four-month-old as opposed to a four-year-old (5). This concept can also be applied to LWM because the degree of closure is more descriptive than a single measurement of length. For example, palates of various widths may have the same average length of movement, but the patient with a larger port width will have a greater degree of VPI. Ideally, we would like to be able to use the preoperative VCR and LWM data to predict the likelihood of successful treatment of VPI with a given surgical technique for treatment of VPI, whether it be double-opposing Z-plasty, sphincter pharyngoplasty or pharyngeal flap. It is with this ultimate goal that we performed the present study.

TABLE 2
Patients with lower preoperative velar closing ratio demonstrate better improvement in hypernasality

Velar closing ratio	Mean hypernasality improvement	n
0–9.33	2.3	4
0.34–0.66	1.5	2
0.67–0.99	1.5	4

TABLE 3
Preoperative lateral wall movement has no effect on hypernasality improvement

Lateral wall movement	Mean hypernasality improvement	n
0–0.25	1.75	2
0.26–0.50	1.60	6
0.51–0.99	2.50	2

TABLE 4
Patients with lower preoperative velar closing ratio (VCR) demonstrate better improvement in nasal emissions (NE)

VCR	−/− NE	−/+ NE	+/− NE	+/+ NE	Resolution of NE, % (n/n)
0–0.33	0	0	4	1	80 (4/5)
0.34–0.66	0	0	1	1	50 (1/2)
0.67–0.99	0	0	0	3	0 (0/3)

Presence of preoperative NE is indicated by + to the left of the slash; presence of postoperative NE is indicated by + to the right of the slash

TABLE 5
Patients with lower preoperative lateral wall movement (LWM) demonstrate better improvement in nasal emissions (NE)

LWM	−/− NE	−/+ NE	+/− NE	+/+ NE	Resolution of NE, % (n/n)
0–0.25	0	0	3	0	100 (3/3)
0.26–0.50	0	0	2	3	40 (2/5)
0.51–0.99	0	0	0	2	0 (0/2)

Presence of preoperative NE is indicated by + to the left of the slash; presence of postoperative NE is indicated by + to the right of the slash

While the present study was not adequately powered to determine statistical significance, it demonstrated trends relating preoperative VCR and LWM with postoperative improvement in speech. Hypernasality was used as the primary end point rather than resolution of VPI because the patients had very poor preoperative velopharyngeal competence and very few reached our definition of complete VPI resolution (no nasal emission and consistent lack of hypernasality). The patients with the worst preoperative VCR experienced the greatest improvement in hypernasality and alleviation of nasal emissions. No relationship between preoperative LWM and improvement of hypernasality was evident. However, patients with worse preoperative LWM exhibited better resolution of nasal emissions. While we had expected that patients with a poor preoperative VCR would demonstrate greater improvement in speech postoperatively, we also expected that those with poor preoperative LWM would not do as well postoperatively because residual lateral velopharyngeal gaps would presumably be present (3,5). Our data suggest that that assumption may be incorrect. Only two of our patients had preoperative LWM >0.5: both of these patients had nasal emissions pre- and postoperatively. However, they did not differ from the other patients in terms of improvement in hypernasality. It is unclear why these patients continued to exhibit nasal emissions postoperatively.

Double-opposing Z-plasty primarily serves to decrease AP gap distance with a small decrease in port width and, by borrowing tissue from the transverse dimension to increase the AP dimension of the velum, the procedure also narrows the width of the velopharyngeal port to some degree. Moreover, the levator muscles are arranged in an overlapping, transverse orientation by this procedure; while the transverse orientation is a characteristic of the normal velum, the overlapping of the levators is not. All but two of our patients underwent intravelar veloplasty during primary palate repair; the sagittal orientation of the levators in these two patients was identified by the presence of a dorsal groove on VNE. Therefore, in the other nine patients who already had transverse levator orientations, double-opposing Z-plasty created a nonphysiological orientation or arrangement of the levator muscles. Previous studies only included patients with sagittally oriented levator muscles because it was reasoned that the double-opposing Z-plasty would provide some benefit by recreating a transverse orientation. Our study had similarly successful outcomes despite the nonphysiological levator arrangement (5). This suggests that the benefit of double-opposing Z-plasty may not be due entirely to manipulation of levator orientation, but also to static increase in palatal length. The two patients with sagittally oriented levators were able to achieve near total velar closure postoperatively, and they exhibited a similar postoperative LWM compared with the patients who did not maintain physiological orientation. This observation reinforces the concept of palatal closure as a complex process impacted by multiple factors including soft palate length, VCR, LWM and levator muscle orientation.

Our study was limited by a relatively small number of patients and by its retrospective nature. Ideally, a correlation between the four possible patient profiles (good VCR/good LWM; good VCR/poor LWM; poor VCR/good LWM; and poor VCR/poor LWM) and surgical success should be determined. Our sample size was too small to allow such an analysis. Therefore, VCR and LWM were analyzed in isolation rather than in combination. While our sample size was small, it does not differ greatly from those published in some other studies (3,5). Further studies are underway to perform a more robust analysis. Nevertheless, our data may provide some insight into preoperative selection criteria for double-opposing Z-plasty. It appears that poor preoperative LWM may not necessarily be a predictor of poor outcome after this procedure.

CONCLUSIONS

In the present study, a trend toward an inverse relationship between preoperative VCR and improvement in hypernasality and resolution of nasal emission was observed in patients who underwent Furlow palatoplasty for VPI. No relationship was noted between the degree of preoperative LWM and average improvement in hypernasality. However, patients with worse preoperative LWM experienced better resolution of nasal emission postoperatively. This finding challenges the commonly held notion that poor preoperative LWM predicts poor outcomes with Furlow palatoplasty for VPI.

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