Int. J. Oral Maxillofac. Surg. 2015; xxx: xxx–xxx
http://dx.doi.org/10.1016/j.ijom.2015.07.006, available online at http://www.sciencedirect.com

International Journal of Oral & Maxillofacial Surgery

Clinical Paper
Cleft Lip and Palate

Use of a modified Furlow Z-plasty as a secondary cleft palate repair procedure to reduce velopharyngeal insufficiency

R. R. Reddy[1], S. G. Reddy[1], B. Banala[1], E. Bronkhorst[2], A. W. Kummer[3], A. M. Kuijpers-Jagtman[2], S. J. Bergé[2]
[1]GSR Institute of Craniofacial Surgery, Vinay Nagar Colony, Saidabad, Hyderabad, India; [2]Radboud University Nijmegen Medical Centre, Nijmegen, Netherlands; [3]Cincinnati Children's Hospital Medical Center and the University of Cincinnati Medical Center, Cincinnati, OH, USA

R. R. Reddy, S. G. Reddy, B. Banala, E. Bronkhorst, A. W. Kummer, A. M. Kuijpers-Jagtman, S. J. Bergé: Use of a modified Furlow Z-plasty as a secondary cleft palate repair procedure to reduce velopharyngeal insufficiency. Int. J. Oral Maxillofac. Surg. 2015; xxx: xxx–xxx. © 2015 Published by Elsevier Ltd on behalf of International Association of Oral and Maxillofacial Surgeons.

Abstract. Cleft palate repair is done to allow for normal speech by separating the oral and nasal cavities and creating a functioning velopharyngeal valve. However, despite cleft palate repair, some patients demonstrate velopharyngeal insufficiency (VPI). An attempt was made to determine the effectiveness of a modified secondary Furlow Z-plasty in improving VPI. Fifty-five children aged between 12 and 15 years, with postoperative VPI following primary palatoplasty, were included in the study. These children underwent a modified Furlow Z-plasty. Nasometry was done to determine the change in velopharyngeal function due to the secondary Furlow Z-plasty by comparing the preoperative with the 1-year postoperative nasalance scores. A test–retest study was performed to determine the reliability of the nasometric measures. Reliability measurements of the nasometer passages revealed good reliability for 18 out of the 25 speech passages. There was a statistically significant reduction in VPI at 1 year postoperative in patients who were treated with the modified Furlow Z-plasty, with a P-value of <0.001 in all passages, except velar plosives, which had a P-value of 0.002. Patients with VPI after primary palatoplasty and treated using a modified Furlow Z-plasty had significantly lower nasalance scores at 1 year postoperative, indicating significantly improved velopharyngeal function.

Key words: cleft palate; secondary palatoplasty; velopharyngeal insufficiency; Furlow Z-plasty; hypernasality; speech; nasometry.

Accepted for publication 14 July 2015

Velopharyngeal insufficiency (VPI) is defined as a structural abnormality that results in incomplete closure of the velopharyngeal valve during the production of oral speech.[1] Among other causes, VPI can be caused by inadequate length and/or movement of the soft palate. Incomplete closure of the velopharyngeal valve can cause hypernasality and/or nasal emission. VPI is considered to be the primary cause of hypernasal speech.[2]

0901-5027/000001+07

VPI has been reported in 5–36% of patients who have undergone primary palatoplasty for cleft palate.[3–5] A variety of treatment options have been described for VPI, including secondary velar palatoplasty.[6–9]

The Furlow double-opposing Z-plasty technique was initially described in 1978 for primary repair of a cleft palate.[10] In recent years, it has been used as a secondary procedure to treat post-palatoplasty VPI.[1,11] The aim of this study was to determine the effectiveness of a modified Furlow Z-plasty in improving VPI by comparing pre- and postoperative nasalance scores.

Materials and methods

Patients

This prospective cohort study was performed between February and December 2011. It was conducted with 55 consecutive non-syndromic patients with complete unilateral cleft lip and palate and postoperative VPI after primary palatoplasty. The patients ranged in age from 12 to 15 years. Of the 55 patients, 30 were male and 25 were female. This research study was approved by the local ethics committee based on the guidelines declared by the Government of India. The parents or guardians of all participants were informed verbally about the study and signed a written informed consent. All patients were operated on by a single surgeon (RRR).

Surgical procedure

A modified Furlow Z-plasty technique was used for each patient. The markings for this procedure are illustrated in Fig. 1.

The marking for the first incision was started with a point on the midline of the soft palate corresponding to the posterior border of the hard palate (point A). The next point was marked at the middle of the base of the reconstructed uvula, or the middle of the posterior border of the soft palate in cases where the uvula had not previously been reconstructed (point B). A line was drawn to connect point A with point B. This line was then extended up to a distance of 10 mm on both the palatopharyngeal arches (points C and D). The incision design of the oral layer was based on the original Furlow Z-plasty, with an anterior limb on the left side and a posterior limb on the right side.[10] The marking for the anterior limb started from point A and followed a path parallel to the posterior border of the hard palate at a distance of 5 mm. It was then extended up to the retromolar area of the left side of the maxilla (point E). The posterior limb extended from point B to the right side of the soft palate at a right angle to line AB (point F). Care was taken to ensure that the lines AB, AE, and BF were equal in length. These incision markings allowed for two flaps to be raised, whereby the one on the left could be rotated posteriorly and the flap on the right side could be rotated anteriorly.

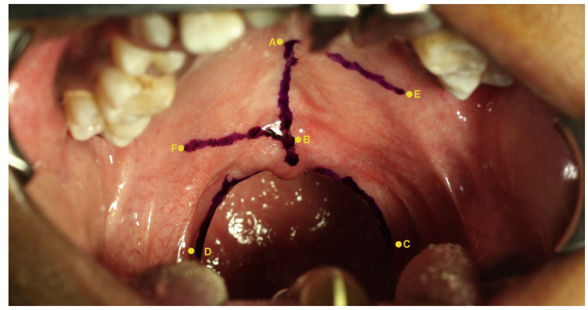

Fig. 1. Marking for the modified Furlow Z-plasty in secondary palatoplasty.

The incision was started on the oral layer from point B to A. The incision was continued from point B to points C and D. After the incisions ABC and ABD were completed, the incision AE was done. A myo-mucosal flap was raised from the nasal layer with the levator muscle bundle initially attached to the oral flap, but dissected away from the oral mucosa after raising the flap. Next, incision BF was performed. In this second flap, the oral mucosa was raised, leaving the levator muscle bundle attached to the nasal layer. The levator muscle bundle was raised from the nasal layer in a second stage. The previously closed nasal layer was left intact and not dissected as would have been done in a traditional Furlow Z-plasty (Fig. 2).

The closure of the nasal layer was started posteriorly by approximating the points C and D and moving anteriorly up to the intact part of the nasal layer. This closure of the nasal layer was done with 4–0 Vicryl sutures (Johnson and Johnson, India) (Fig. 3). The approximation of the

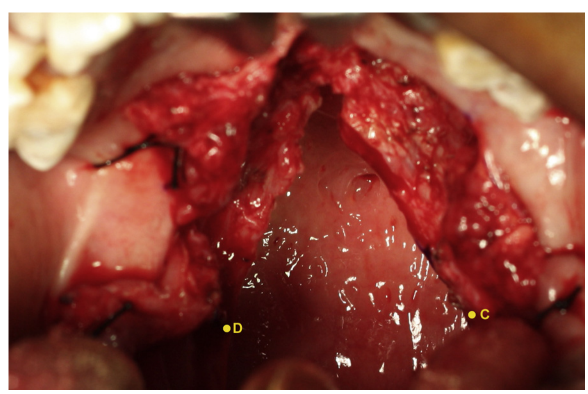

Fig. 2. Extension of the nasal layer.

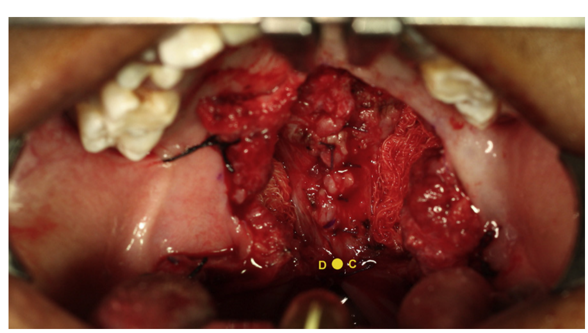

Fig. 3. Closure of the nasal layer.

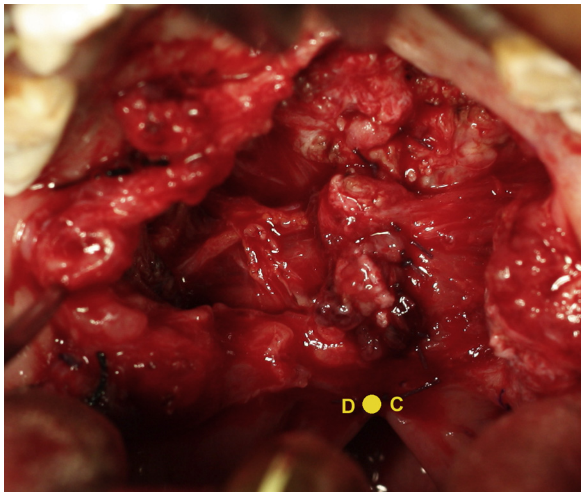

Fig. 4. Muscle approximation of levator veli palatini, palatoglossus, and palatopharyngeus muscles.

Fig. 5. Preoperative picture of the previously repaired soft palate cleft.

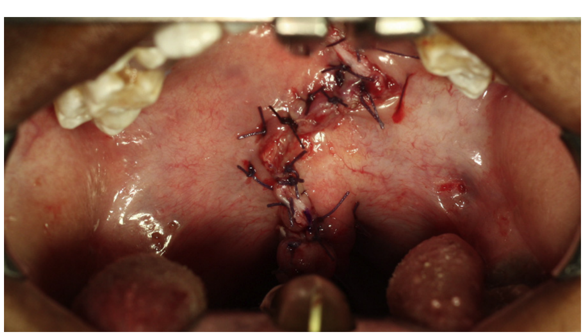

Fig. 6. Postoperative result of the secondary cleft palate surgery.

levator muscle bundle was done with 4–0 PDS II sutures (Johnson and Johnson, India) by repositioning the bundle transversely and posteriorly (Fig. 4). Closure of the oral layer was done with a Z-plasty by transposing flap BF anteriorly and AE posteriorly with 4–0 Vicryl sutures (Johnson and Johnson, India) (Figs 5 and 6).

The result of this procedure ensured a lengthening of the soft palate by up to 10 mm and ensured that the levator muscle bundle along with the palatoglossus and palatopharyngeus muscles were positioned at the posterior-most part of the repaired soft palate.

VPI analysis

Nasometry is a method of measuring the acoustic correlates of velopharyngeal function during speech.[12] A nasometer captures data regarding acoustic energy from both the nasal cavity (N) and the oral cavity (O) during speech and then calculates the average ratio of nasal over total (nasal plus oral) acoustic energy. This ratio is converted to a percentage value and is called the nasalance score. The nasalance score can be depicted as follows: nasalance = $N/(N + O) \times 100$. When standardized passages are used, nasalance scores can be compared.

Using a Nasometer-II model 6450 (KayPENTAX, Lincoln Park, NJ, USA), each patient was tested both preoperatively and at 1 year postoperative by a single speech therapist (BB). The passages that were used were from a revised version of the Simplified Nasometric Assessment Procedures Test (SNAP Test-R), described by MacKay and Kummer in 2005.[13] The SNAP Test-R uses three subtests: (1) the syllable repetition/prolonged sounds subtest, (2) the picture-cued subtest, and (3) the reading subtest.

The syllable repetition/prolonged sounds subtest includes 14 consonant–vowel (CV) syllables of pressure-sensitive consonants combined with either a low vowel (/ɑ/ as in ''father'') or a high vowel (/i/ as in ''heat''). It also includes two prolonged vowels and two prolonged consonants. This test provides phonetic specificity of hypernasality and/or nasal emission. The picture-cued subtest contains passages that are essentially phonetically homogeneous. For each passage, a carrier phrase is used with pictures to form complete sentences. Each passage has three pictures to elicit three sentences. Each sentence is said twice. There is a passage for each of the following: bilabial plosives, lingual–alveolar plosives, velar plosives, sibilant fricatives, and nasals. The reading subtest consists of two short, easy-to-read passages, one loaded with plosives and the other loaded with sibilants. These passages are more heterogeneous phonetically than the other two subtests, but are still more homogeneous than the 'phonetically-balanced' passages that are often used in clinical nasometry.[13]

The language used to perform this test was English. Children who were unable to read English were asked to repeat the stimulus after the examiner. In such a case, the nasometer was activated only when the patient was speaking.

For each patient, the mean nasalance score was calculated for each speech sample using the nasometer software. The mean of all individual patient scores for each passage was then calculated for the preoperative evaluation and also for the 1-year postoperative evaluation. Comparisons of the pre- and postoperative nasalance scores were performed using the paired *t*-test.

Test–retest reliability was determined by repeating the test 1 h after it was first administered for 25 random subjects. Using the results, a paired *t*-test was performed.

Results

Reliability analysis

Analysis of the test–retest measurements revealed various outcomes (Table 1). A reliability of lower than 0.8, a large duplicate measurement error (DME), or a *P*-value lower than 0.05 are indicators of relatively low measurement performance. For 18 out of 25 outcomes, the differences between the two measurements showed statistically significant reliability. The following passages showed reliability below 0.8, which is considered low: /sɑ, sɑ, sɑ.../, /ʃɑ, ʃɑ, ʃɑ.../, prolonged /i/, prolonged /m/, the picture-cued subtests of lingual–alveolar plosives and velar plosives, and the reading passages subtest of bilabial plosives with nasals.

Comparison of pre- and postoperative nasalance values

Notwithstanding the limitations of the test–retest measurements, the differences between nasalance scores pre- and postoperatively were very clear. For all outcomes, the difference showed a statistically significant reduction in VPI postoperatively. For all but one outcome in the three subtests, a *P*-value of <0.001 was found. The values for the velar plosive sound also showed a reduction in VPI, with a *P*-value of 0.002 (Table 2).

Discussion

VPI is a common problem in patients with cleft palate, despite the palate repair. The rate of VPI after primary palatoplasty reported by various centres has ranged from 5% to 36%.[4–6]

VPI can significantly affect the quality and intelligibility of the child's speech, and as a consequence, affect communication.[7–9] Because hypernasality is a characteristic feature of VPI, measuring nasalance pre- and postoperatively is an appropriate method to evaluate the effectiveness of surgical treatment of VPI.

There are several surgical methods to manage VPI, including pharyngoplasties, palatal lengthening procedures, and even pharyngeal augmentation.[14–19] Pharyngoplasties, such as the superior-based

Table 1. Test–retest reliability ($n = 25$).[a]

	Reliability	Duplicate measurement error	Difference	*P*-value	95% CI
1. Syllable repetition/prolonged sounds subtest					
Oral + /ɑ/ syllables					
pɑ, pɑ, pɑ...	0.945	2.33	1.6	0.023	(0.2 to 3.0)
tɑ, tɑ, tɑ...	0.897	3.2	2.8	0.006	(0.9 to 4.6)
kɑ, kɑ, kɑ...	0.891	3.23	2.8	0.005	(0.9 to 4.7)
sɑ, sɑ, sɑ...	0.64	7.69	6.1	0.01	(1.6 to 10.6)
ʃɑ, ʃɑ, ʃɑ...	0.639	6.33	5	0.01	(1.3 to 8.7)
Oral + /i/ syllables					
pi, pi, pi...	0.854	6.43	5.4	0.006	(1.7 to 9.2)
ti, ti, ti...	0.856	6.39	3.2	0.089	(−0.5 to 6.9)
ki, ki, ki...	0.867	5.94	4.6	0.011	(1.1 to 8.1)
si, si, si...	0.905	4.93	3	0.046	(0.1 to 5.9)
ʃi, ʃi, ʃi...	0.954	3.66	2.3	0.044	(0.1 to 4.5)
Nasal + /ɑ/ syllables					
mɑ, mɑ, mɑ...	0.961	2.42	0.1	0.862	(−1.3 to 1.5)
nɑ, nɑ, nɑ...	0.961	2.53	−0.1	0.868	(−1.6 to 1.4)
Nasal + /i/ syllables					
mi, mi, mi...	0.984	1.66	0.5	0.317	(−0.5 to 1.4)
ni, ni, ni...	0.969	2.1	1.1	0.082	(−0.1 to 2.3)
Prolonged sounds					
Prolonged /ɑ/	0.977	1.47	0.6	0.137	(−0.2 to 1.5)
Prolonged /i/	0.605	9.54	1.6	0.559	(−4.0 to 7.2)
Prolonged /s/	0.988	3.07	0.8	0.39	(−1.0 to 2.6)
Prolonged /m/	0.663	3.69	−1.5	0.169	(−3.6 to 0.7)
2. Picture-cued subtest					
Oral passages					
Bilabial plosives	0.873	4.62	1.1	0.417	(−1.6 to 3.8)
Lingual–alveolar plosives	0.685	6.41	0.1	0.948	(−3.6 to 3.9)
Velar plosives	0.339	18.08	4.6	0.377	(−6.0 to 15.2)
Sibilant fricatives	0.938	3.41	−0.9	0.371	(−2.9 to 1.1)
Nasal passage					
Nasals	0.849	3.67	0.6	0.543	(−1.5 to 2.8)
3. Reading passages subtest					
Passages (reading)					
Bilabial plosives (with nasals)	0.751	5.98	−0.6	0.744	(−4.1 to 2.9)
Sibilant fricatives (without nasals)	0.956	2.57	1.6	0.042	(0.1 to 3.1)

CI, confidence interval.

[a] Key to phonetic symbols: /ʃ/ = ɑsh''; /ɑ/ = vowel in ''father''; /i/ = vowel in ''heat''.

Please cite this article in press as: Reddy RR, et al. Use of a modified Furlow Z-plasty as a secondary cleft palate repair procedure to reduce velopharyngeal insufficiency, *Int J Oral Maxillofac Surg* (2015), http://dx.doi.org/10.1016/j.ijom.2015.07.006

Table 2. Pre- and postoperative analysis of nasalance ($n = 55$).[a]

	Mean preoperative nasalance	Mean postoperative nasalance	Difference	*P*-value	95% CI
1. Syllable repetition/prolonged sounds subtest					
Oral + /ɑ/ syllables					
pɑ, pɑ, pɑ. . .	33.64	20.55	13.09	<0.001	(9.58 to 16.60)
tɑ, tɑ, tɑ. . .	34.18	22.18	12	<0.001	(8.59 to 15.41)
kɑ, kɑ, kɑ. . .	34.45	23.25	11.2	<0.001	(7.56 to 14.84)
sɑ, sɑ, sɑ. . .	38.53	28.02	10.51	<0.001	(6.59 to 14.42)
ʃɑ, ʃɑ, ʃɑ. . .	39.58	27.78	11.8	<0.001	(8.50 to 15.10)
Oral + /i/ syllables					
pi, pi, pi. . .	58.75	42.38	16.36	<0.001	(11.62 to 21.11)
ti, ti, ti. . .	60.55	44.76	15.78	<0.001	(11.36 to 20.2)
ki, ki, ki. . .	62.56	47.42	15.15	<0.001	(10.54 to 19.75)
si, si, si. . .	62.52	47.17	15.35	<0.001	(11.08 to 19.62)
ʃi, ʃi, ʃi. . .	61.21	44.45	16.75	<0.001	(12.43 to 21.08)
Nasal + /ɑ/ syllables					
mɑ, mɑ, mɑ. . .	59.07	51.51	7.56	<0.001	(5.24 to 9.89)
nɑ, nɑ, nɑ. . .	59.67	52.11	7.56	<0.001	(5.03 to 10.10)
Nasal + /i/ syllables					
mi, mi, mi. . .	75.04	68.24	6.8	<0.001	(4.30 to 9.30)
ni, ni, ni. . .	74.25	70.16	4.09	<0.001	(1.83 to 6.35)
Prolonged sounds					
Prolonged /ɑ/	31.82	19.93	11.89	<0.001	(9.79 to 13.99)
Prolonged /i/	66.11	46.96	19.15	<0.001	(15.89 to 22.4)
Prolonged /s/	65.76	48.71	17.05	<0.001	(11.55 to 22.55)
Prolonged /m/	93.65	89.89	3.76	<0.001	(2.49 to 5.04)
2. Picture-cued subtest					
Oral passages					
Bilabial plosives	52.22	36.91	15.31	<0.001	(11.24 to 19.38)
Lingual–alveolar plosives	47.56	34.35	13.22	<0.001	(9.28 to 17.16)
Velar plosives	50.15	40.09	10.05	0.002	(3.76 to 16.35)
Sibilant fricatives	51.64	38.71	12.93	<0.001	(8.99 to 16.86)
Nasal passage					
Nasals	62.24	57.53	4.71	<0.001	(2.96 to 6.46)
3. Reading passages subtest					
Passages (reading)					
Bilabial plosives (with nasals)	50.78	36.22	14.56	<0.001	(11.70 to 17.41)
Sibilant fricatives (without nasals)	50.69	36.43	14.26	<0.001	(10.64 to 17.88)

CI, confidence interval.
[a] Key to phonetic symbols: /ʃ/ = ɑsh''; /ɑ/ = vowel in ''father''; /i/ = vowel in ''heat''.

pharyngeal flap or the sphincter pharyngoplasty, aim to correct VPI by reducing the size of the velopharyngeal port.[20] On the other hand, palatal lengthening procedures, including the Furlow Z-plasty[23] and the radical intravelar veloplasty of Sommerlad et al.,[21] use the soft palate and its muscles to improve palatal length. The ultimate goal of VPI surgery is to achieve closure of the velopharyngeal port during speech, without obstructing the airway.

The double-opposing Z-plasty was introduced by Leonard Furlow as a primary procedure for initial soft palate cleft repair.[10] The Z-plasty has recently been shown to be effective as a secondary surgical procedure to treat VPI.[22] The first report of the use of the Furlow palatoplasty as a secondary procedure for VPI came from Randall et al. in 1986.[11] In 1994, Chen et al. first investigated the use of the Furlow palatoplasty in secondary palatoplasty scientifically and found that it had a positive effect on velopharyngeal function, particularly in patients with a velopharyngeal gap of less than 5 mm.[23] These findings were confirmed by D'Antonio et al. in 2000[24] and Sie et al. in 2001.[22] By comparing pre- and postoperative measurements taken from cephalometric X-rays, D'Antonio et al. showed that the Furlow double-opposing Z-plasty is capable of increasing the length of the soft palate.[24]

In the present study, the double-opposing Z-plasty technique for secondary repair of the soft palate was modified. The traditional Furlow technique was used to dissect and repair the oral mucosa. The modification was in the preparation of the nasal layer and in the dissection of the levator veli palatini muscle bundle. The nasal layer from the primary surgery was left intact. The decision not to divide the nasal layer was made to avoid the additional scarring and surgical wound breakdown that could result due to reduced vascularity from dissection during the primary palatoplasty. If any lengthening of the nasal layer was required, it was done by extending the incision over the posterior faucial pillar. This resulted in a lengthening of the soft palate and also gave the operator access to the palatopharyngeus muscle, in order to improve the mobility of the soft palate.

In the traditional Furlow Z-plasty, the palatal muscles are dissected only from one of their two mucosal covers.[10] In the study patients, an intravelar veloplasty for the muscle was performed in the secondary cleft soft palate repair. Intravelar veloplasty was first described by Kriens in 1970.[25] Sommerlad, who later introduced the radical intravelar veloplasty, described it as the separation of the velar muscle mass (i.e., levator, palatopharyngeus, and palatoglossus muscles) from the oral and nasal mucosa and from the posterior border of the maxilla. The levator is identified within the velar muscle mass and traced laterally to the levator tunnel, where the levator enters the velum by passing above the cranial margin of the superior constrictor. Separation of the velar muscle mass from the nasal component of the tensor then allows for untethered retropositioning of the levator.[26] Though both Kriens and Sommerlad described the technique of intravelar veloplasty in primary palatoplasty, the authors feel the radical intravelar veloplasty is also appropriate for secondary palate repair. Therefore, in the study patients, the muscle bundle was separated from both mucosal covers and they were positioned posteriorly to improve the mobility of the soft palate muscles.

In addition to the perceptual assessment, different instrumental techniques to evaluate the results of VPI surgery have been described by various authors. The most common are nasendoscopy, multiview videofluoroscopy, and nasometry. As nasometry is not invasive and yields objective data, this method is commonly used for pre- and postoperative comparisons.[27]

The nasometer has been used since 1986 for the clinical assessment of nasal resonance. It provides an objective measure of nasality by capturing both oral and nasal acoustic energy during speech production and calculating a nasalance score. In this study, the nasalance scores were measured through the MacKay–Kummer SNAP Test-R developed by MacKay and Kummer.[13]

In this study the test–retest reliability of the SNAP Test-R scores showed the measurements to be reliable in 18 out of 25 tests. This is not surprising, in that when there is a velopharyngeal opening during speech, the size of the opening varies with effort, as can be seen through nasopharyngoscopy. Of course, the size of the opening determines the severity of the hypernasality and nasal emission.

The important finding of this study is that, despite the possibility of test–retest variability, all subjects showed a reduction in the nasalance score postoperatively. In addition, the differences between the measurements before and after treatment were large enough not to be due to test–retest variability alone. It is also important to note that the scores on the nasal passages were normal postoperatively, suggesting a lack of postoperative airway obstruction.

Chen and colleagues studied secondary palatoplasty using the traditional Furlow double-opposing Z-plasty procedure in 18 patients. They obtained velopharyngeal competence in 16 patients (89%).[23] They reported that good results were obtained in the patients whose velopharyngeal gap was less than 5 mm, but not in those with a velopharyngeal gap larger than 10 mm. They considered 5 mm as a criterion for this operation to be indicated.[23] Another study on Furlow palatoplasty for secondary repair was performed by Lindsey and Davis.[1] They obtained velopharyngeal closure in seven of eight patients (87.5%) whose velopharyngeal gap was between 6 and 8 mm. Sie et al. reported a complete resolution of velopharyngeal insufficiency in 39.6% of 48 patients.[22] Postoperatively, 31.4% of patients had mild or moderate insufficiency and 12.5% had severe insufficiency.

The present study showed that for 24 out of the 25 speech passages, the mean nasalance scores of the 55 patients showed a statistically significant improvement postoperatively (P-value <0.001). The improvement in nasalance scores (which are objective measures) provides further evidence that the modified Furlow Z-plasty procedure can decrease a velopharyngeal opening by lengthening the velum.

Although there was an improvement in the mean postoperative score for the velar plosives subtest, the improvement for that one test was not as significant as the other passages (P-value 0.002). This can be explained by the possibility of variability with that one passage, particularly considering the fact that the two syllable subtest of velars (/kɑ, kɑ, kɑ. . ./ and /ki, ki, ki. . ./) showed significant improvement.

Although many patients in this study had postoperative nasalance scores in the normal range, the *averages* of the postoperative scores of all the patients were still higher than normal. Because patients for this study were selected consecutively and not based on gap size, it may be that, as reported by Chen and colleagues,[23] the Furlow Z-plasty is less effective for patients with large velopharyngeal gaps (i.e., 5 mm or more). Another probable reason for this is the fact that many of the patients continued to have compensatory articulation productions postoperatively.

Compensatory productions for VPI are typically produced in the pharynx, and therefore, they continue to cause nasal emission, even after the function of the velopharyngeal valve has been surgically corrected. Therefore, the higher-than-normal postoperative nasalance scores in some patients in this study are due to abnormal speech articulation rather than abnormal structure and function of the velopharyngeal valve.

There are limitations to this study. Firstly, there was no way of knowing which technique was used to repair the cleft palate primarily. All surgeries except six were performed by other surgeons and the patients had no case histories with them. The six that were performed at the study hospital were done using Bardach's technique. Secondly, the velopharyngeal gap present preoperatively was not determined in terms of a determinate distance. However, velopharyngeal insufficiency was confirmed using nasometry as an indication to perform the secondary nasal repair.

In conclusion, a comparison of the collective pre- and postoperative nasalance scores of a cohort of patients with VPI after primary palatoplasty and who were treated with secondary palatoplasty using a modified Furlow Z-plasty showed significant improvement in VPI at 1 year postoperative. In addition, the nasalance scores suggested a lack of airway obstruction postoperatively.

Funding

Cleft Children International, Zurich Switzerland, for treatment grants to provide free surgery for patients included in this study.

Competing interests

None.

Ethical approval

Ethical approval was given as specified by the Government of India's norms by a six-member ethics committee appointed by the hospital where this study was conducted. The reference number of the judgement is GSRICFS/ETHCOMM/DEC2010/03.

Patient consent

Written patient consent was obtained.

References

1. Lindsey WH, Davis PT. Correction of velopharyngeal insufficiency with Furlow palatoplasty. *Arch Otolaryngeal Head Neck Surg* 1996;**122**:881–4.

2. Saxman JH. A call for new directions in cleft palate speech research. *Cleft Palate J* 1972;**9**:274–9.
3. Dorf DS, Curtin JW. Early cleft palate repair and speech outcome. *Plast Reconstr Surg* 1982;**70**:74–81.
4. Bardach J, Morris HL. *Multidisciplinary management of cleft lip and palate*. Philadelphia: Saunders; 1990: 303–65.
5. Hudson DA, Grobbelaar AO, Fernandes DB, Lentin R. Treatment of velopharyngeal incompetence by the Furlow Z-plasty. *Ann Plast Surg* 1995;**34**:23–6.
6. Seyfer AE, Prohazka D, Leahy E. The effectiveness of the superiorly based pharyngeal flap in relation to the type of palatal defect and timing of the operation. *Plast Reconstr Surg* 1988;**82**:760–4.
7. Riski JE, Ruff GL, Georgiade GS, Barwick WJ, Edwards PD. Evaluation of sphincter pharyngoplasty. *Cleft Palate J* 1992;**29**:254–61.
8. Trigos I, Ysunza A, Gonzalez A, Vazquez MC. Surgical treatment of borderline velopharyngeal insufficiency using homologous cartilage implantation with video nasopharyngoscopic monitoring. *Cleft Palate J* 1988;**25**:167–70.
9. Deren O, Ayhan M, Tuncel A, Görgü M, Altuntaş A, Kutlay R, et al. The correction of velopharyngeal insufficiency by Furlow palatoplasty in patients older than 3 years undergoing Veau–Wardill–Kilner palatoplasty: a prospective clinical study. *Plast Reconstr Surg* 2005;**116**:85–93.
10. Furlow LT. Cleft palate repair by double-opposing Z-plasty. *Plast Reconstr Surg* 1986;**78**:724–36.
11. Randall P, La Rossa D, Solomon M, Cohen M. Experience with the Furlow double reversing Z-plasty for cleft palate repair. *Plast Reconstr Surg* 1986;**77**:569–74.
12. Kummer AW. Nasometry. In: Kummer AW, editor. *Cleft palate and craniofacial anomalies: the effects on speech and resonance*. Clifton Park, NY: Cengage Learning; 2014. p. 400–34.
13. Kummer AW. *Cleft palate and craniofacial anomalies: effects on speech and resonance*. 2nd ed. Thomson Delmar Learning; 2008 . http://www.kaypentax.com/index.php?option=com_product&view=product&Itemid=3&controller=product_innerpage&rec_id=50&no_id=2.
14. Albery E, Russell J. *Cleft palate sourcebook*. Bicester, UK: Winslow Press; 1994.
15. Tudor C, Selley W. A palatal training appliance and a visual aid for use in the treatment of hypernasal speech. *Br J Disord Commun* 1974;**9**:117–22.
16. Turner GE, Williams WN. Fluoroscopy and nasoendoscopy in designing palatal lift prostheses. *J Prosthet Dent* 1991;**66**:63–71.
17. Abramson DL, Marrinan EM, Mulliken JB. Robin sequence: obstructive sleep apnea following pharyngeal flap. *Cleft Palate Craniofac J* 1997;**34**:256–60.
18. Tachimura T, Nohara K, Hara H, Wada T. Effect of placement of a speech appliance on levator veli palatini muscle activity during blowing. *Cleft Palate Craniofac J* 1999;**36**:224–31.
19. Golding-Kushner KJ, Cisneros G, LeBlanc E. Speech bulbs. In: Shprintzen RJ, Bardach J, editors. *Cleft palate speech management: a multidisciplinary approach*. St. Louis: Mosby; 1995. p. 352–63.
20. Sloan GM. Posterior pharyngeal flap and sphincter pharyngoplasty. *Cleft Palate Craniofac J* 2000;**37**:112–21.
21. Sommerlad BC, Mehendale FV, Birch MJ, Sell D, Hattee C, Harland K. Palate re-repair revisited. *Cleft Palate Craniofac J* 2002;**39**:295–307.
22. Sie CY, Tampakopoulou DA, Sorom J, Gruss JS, Eblen LE. Results with Furlow palatoplasty in management of velopharyngeal insufficiency. *Plast Reconstr Surg* 2001;**108**:17–25.
23. Chen PK, Wu JT, Chen Y, Noordhoff SM. Correction of secondary velopharyngeal insufficiency in cleft palate patients with the Furlow palatoplasty. *Plast Reconstr Surg* 1994;**94**:933–41.
24. D'Antonio LL, Eichenberg BJ, Zimmerman GJ, Patel S, Riski JE, Herber SC, et al. Radiographic and aerodynamic measures of velopharyngeal anatomy and function following Furlow Z-plasty. *Plast Reconstr Surg* 2000;**106**:539–49.
25. Kriens O. Fundamental anatomic findings for an intravelar veloplasty. *Cleft Palate J* 1970;**7**:27–36.
26. Fisher DM, Sommerlad BC. Cleft lip, cleft palate, and velopharyngeal insufficiency. *Plast Reconstr Surg* 2011;**128**:342–60.
27. Brunnegard K, van Doorn J. Normative data on nasalance scores for Swedish as measured on the nasometer: influence of dialect, gender and age. *Clin Linguist Phon* 2009;**23**:58–69.

Address:
Rajgopal R. Reddy
GSR Institute of Craniofacial Surgery
 # 17-1-383/55
Vinay Nagar Colony
I S Sadan
Saidabad
Hyderabad 500 059
India
Tel: +91 40 65764884; Fax: +91 40 24530000
E-mail: raj@craniofacialinstitute.org

Please cite this article in press as: Reddy RR, et al. Use of a modified Furlow Z-plasty as a secondary cleft palate repair procedure to reduce velopharyngeal insufficiency, *Int J Oral Maxillofac Surg* (2015), http://dx.doi.org/10.1016/j.ijom.2015.07.006