

An Anatomic Evaluation of the Furlow Double Opposing Z-Plasty Technique of Cleft Palate Repair'

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Abstract

The aim of this investigation was to examine velar anatomy following the Furlow double opposing Z-plasty in order to analyse the theoretical effects of this technique. Thirty patients with cleft lip and/or cleft palate who underwent primary Furlow palatoplasties between 1989 and 1994 were reviewed. The mean age at the time of surgery was 6.4 months. Evaluation was performed at a mean time of 2.9 years postoperatively, and consisted of oral examination of the position of the velar dimple and measurements of velar dimensions from standard lateral cephalograms. A comparative statistical analysis of velar length (n = 17) and thickness (n = 14) was performed using 2 historical control groups (non-cleft norms and non-Furlow cleft palate repairs). The Furlow procedure produced posterior dimples in 19 of 26 patients adequately rated on oral examination, suggesting successful repositioning of the velar musculature in transverse orientation. The mean velar length was not significantly different from that of norms (being 0.72 mm less), suggesting that the Furlow Z-plasty results in the attainment of near normal velar length. In contrast, the mean velar length was 0.46 mm greater compared to non-Furlow repairs. Although this difference was not statistically significant, it suggests that the Furlow Z-plasty may be more effective in increasing velar length compared to non-Furlow palatoplasty techniques. Velar thickness was significantly greater compared to both norms (P = 0.002) and non-Furlow repairs (P = 0.001). These data suggest that the Furlow double opposing Z-plasty repositions the velar muscles in transverse orientation, and increases both velar length and thickness, lending weight to the theoretical effects of this procedure. The anatomic basis of these changes and their functional implications are discussed.

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Introduction

The Furlow double opposing Z-plasty has gained considerable popularity since its introduction approximately a decade ago,¹ and is currently a favoured method of both primary and secondary palatoplasty in many centres.²⁻⁸ Several theoretical advantages make this technique of cleft palate repair attractive. It incorporates a repositioning of the levator veli palatini and palatopharyngeus muscles in a transverse orientation, thus providing functional benefits similar to the intravelar veloplasty.⁹ The Z-plasty lengthens the velum, which potentially reduces the anteroposterior dimension of the velopharyngeal port. Although lengthening of the velum

in itself is not necessarily advantageous, a functional lengthening of the soft palate would appear to a desirable outcome. The Furlow technique also avoids a straight line repair, which in theory reduces the risk of longitudinal shortening of the velum. Finally, when used for the closure of isolated clefts of the soft palate, it obviates the need for raising mucoperiosteal hard palatal flaps, which theoretically causes less interference with maxillary growth than procedures that involve subperiosteal dissection in the hard palate.

Infrequent reference has been made to other possible effects of the Furlow procedure. These include division of the musculus uvulae and reorientation of its fibres in

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a morphologically abnormal oblique position, as these fibres are inevitably included in the limbs of the nasal Z-plasty.¹⁰ Although the other velar muscles (namely levator veli palatini and palatopharyngeus) are reoriented correctly in the transverse position as a result of transposition of the myomucosal flaps, the resulting overlap of the muscles across the midline is morphologically abnormal, since the normal levator veli palatini and palatopharyngeus muscles do not overlap to a significant degree.⁹ However, this muscle overlap would theoretically thicken the velum, possibly compensating for the disruption of the musculus uvulae and reducing the distance between its nasal surface and the posterior pharyngeal wall.^{9,10} Although this effect is theoretically advantageous, it must be weighed against the lateral tension which is created by the transposition of the Z-plasty flaps as excessive lateral tension could adversely affect velar stretch and elevation in the anteroposterior direction. This is of greater concern when the Furlow procedure is used for the repair of wide clefts, in which a greater magnitude of transposition is required, particularly when Furlow's original technique of using large flaps without lateral releasing incisions is employed. Additionally, when large flaps are used in wide clefts, the tension on the mucosal suture lines is likely to be greater, increasing the risk of dehiscence and fistula formation, unless lateral releasing incisions are simultaneously made.²

It is evident, therefore, that the Furlow procedure offers a mix of theoretical advantages and potential drawbacks. Although previous authors have reported favourable results using this technique,²⁻⁸ these investigators have not analysed the anatomic effects of the procedure. The purpose of this study, therefore, was to examine velar anatomy in patients with cleft palate following the Furlow palatoplasty and to correlate these findings with the theoretical effects of this procedure. Specifically, this investigation sought to answer the following three questions: Does the Furlow Z-plasty (1) result in transverse orientation of the velar musculature (2) lengthen the velum and (3) increase velar thickness?

Patients and Methods

The records of all patients who had undergone the Furlow double opposing Z-plasty between 1989 and 1994 at Scottish Rite Children's Medical Center in Atlanta, Georgia, USA were examined. In order to reduce variability, the following categories of patients were excluded: syndromic patients, patients with hearing loss or developmental delay, patients who had undergone other simultaneous velopharyngeal surgical procedures, and patients who had been lost to follow-up. This left 30 patients as the study group.

There were 15 males and 15 females. The mean age at the time of surgery was 6.4 months (range 2.75 to 12.5

months). The latest speech evaluations were performed at a mean time of 2.9 years postoperatively. The mean age at evaluation was 4.3 years (range 1.4 to 6.5 years). The cleft types are summarised in Table I. The surgery was performed by two surgeons, all of whom used the Randall-LaRossa modification of Furlow's original technique.* The oral myomucosal flap was raised on the patient's left side, whereas the nasal myomucosal flap was raised on the right side.

Comprehensive postoperative evaluations were conducted by a single speech pathologist experienced in the management of speech disorders associated with cleft palate. For the purpose of this report, only the evaluations relevant to the aims of this study will be described. These comprised oral examination of the velum and lateral cephalometric radiography.

Oral examination included dichotomous ratings of velar mobility (active or poor) during the phonation of the sound /ah/ and or /ka/. Mobility was rated to be active when there was easily visible contraction of the velar muscles with dimpling of the soft palate. If it was not possible to make these observations clearly, mobility was rated as poor. In addition, the position of the velar dimple was rated (anterior or posterior). This dimple reflects the orientation of the velar muscles: an anterior dimple, defined as occurring within the anterior third of the velum, is consistent with an anteroposterior orientation of the muscles, such as is observed if no or inadequate muscle repositioning is performed during palatoplasty. In contrast, a posterior dimple, seen lying within the posterior third of the velum, is usually associated with a transverse orientation of the velar muscles, which is typically seen when there has been adequate muscle repositioning during palatoplasty.

Radiographic assessment consisted of measurements of velopharyngeal dimensions from standard lateral cephalometric radiographs taken at rest according to the technique of Subtelny (Fig. 1).¹¹ For the purpose of this study, measurements were made of velar length and thickness.

Statistical Analysis

The radiographic data on velar length and thickness were compared with two sets of historical comparison groups: Subtelny's norms" and similar data from

TABLE I: DIAGNOSIS BY CLEFT TYPE

Diagnosis	n
Unilateral cleft lip and palate	16
Bilateral cleft lip and palate	4
Isolated cleft palate	9
Submucous cleft palate	1
Total	30

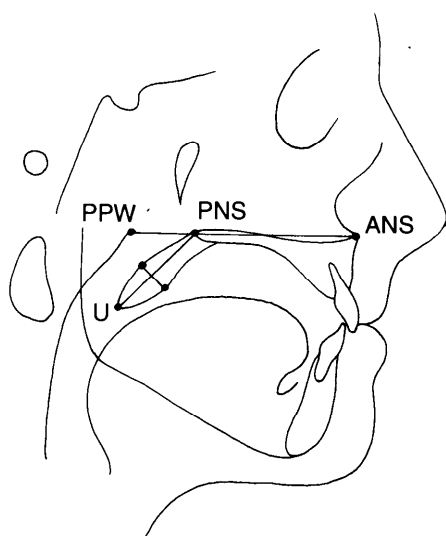


Fig. 1. Measurement of velar dimensions from standard lateral cephalogram taken at rest according to the technique of Subtelny.¹¹ Velar length was measured from the posterior nasal spine (PNS) to the tip of uvula (U). Velar thickness was measured across the thickest part of velum, usually at its midpoint. PPW: posteriorpharyngeal wall; ANS: anterior nasal spine.

Mazaheri et al¹² obtained from cleft palate patients who had undergone non-Furlow primary palatoplasties. In these comparisons, the study patients were age and gender matched (with the Subtelny norms¹¹), and age, gender and diagnosis matched (with the patients of Mazaheri et al¹²). Mean differences and standard deviations were calculated, and their significance was analysed using one-sided paired *t* and Wilcoxon signed rank tests.

Results

Velar Dimples

Ratings of the activity of velar motion by oral examination were obtained in 26 patients. Nineteen of the 26 patients demonstrated active velar motion with posterior velar dimples. The remaining 7 patients had poor velar motion with indeterminate velar dimple positions due to the poor motion.

Velar Length

Adequate radiographic data were obtained in 17 patients with respect to velar length (Table II). This was first compared with the Subtelny norms.¹¹ The mean difference in age and gender matched comparisons was computed to be -0.72 (standard deviation 5.86), i.e. velar length was slightly less in the study group. This difference was not statistically different (one-sided paired *t*-test *P* = 0.31, one-sided Wilcoxon signed rank test *P* = 0.40).

In contrast, when the velar lengths of the study patients were compared with age, gender and diagnosis matched controls from the report of Mazaheri et al,¹² the

TABLEII: VELAR LENGTH IN MILLIMETERS AMONG STUDY PATIENTS, AGE AND GENDER MATCHED SUBTELNY NORMS,¹¹ AND AGE, GENDER AND DIAGNOSIS MATCHED PATIENTS FROM MAZAHERI ET AL¹²

Patient no.	Velar length	Subtelny norms (SD)	Mazaheri data (SD)
1	29	25.2 (1.433)	24.33 (3.06)
2	23.8	23.9 (1.0677)	23.79 (2.26)
3	34	27.5 (2.8089)	25.8 (2.49)
4	30.4	24.8 (1.1685)	23.78 (1.57)
5	24	25.2 (1.433)	23.79 (2.26)
6	28	23.9 (1.6423)	23.79 (2.26)
7	20	25.2 (1.433)	23.78 (1.57)
8	33.3	25.8 (1.5438)	24.53 (2.01)
9	31.5	25.6 (1.4661)	24.53 (2.01)
10	20.9	25.8 (1.5438)	24.63 (2.91)
11	11.4	25.6 (1.4661)	24.33 (3.06)
12	29.8	33.6 (1.2477)	26.03 (2.11)
13	21.5	23.9 (1.0677)	23.78 (1.57)
14	23.8	23.9 (1.0677)	24.06 (2.94)
15	19	27.5 (2.8089)	24.33 (3.06)
16	21.9	25.2 (1.433)	23.79 (2.26)
17	22	24 (1.6423)	24.06 (2.94)

SD: standard deviation

mean difference was + 0.46 (standard deviation 5.83), i.e. velar length was slightly greater in the study patients. However, this difference was also not statistically significant (one-sided paired *t*-test *P* = 0.38, one-sided Wilcoxon signed rank test *P* = 0.35).

Velar Thickness

Velar thickness in the study patients (*n* = 14, Table III) was compared with age and gender matched Subtelny norms.¹¹ The mean thickness in the study group was 2.34 mm greater than the controls (standard deviation 2.58). This difference was statistically significant (one-sided paired *t*-test *P* = 0.002, Wilcoxon signed rank test *P* = 0.003).

In age, gender and diagnosis matched comparisons with the data of Mazaheri et al,¹² the mean velar thickness in the Furlow patients was 2.83 mm greater (standard deviation 2.62). This difference was also statistically significant (one-sided paired *t*-test *P* = 0.001, Wilcoxon signed rank test *P* = 0.002).

Discussion

Velar Dimples

In all the patients in whom active velar motion was observed (*n* = 19), the position of the velar dimple was posterior. This finding suggests that when performed as described,^{1,2} the Furlow palatoplasty repositions the levator veli palatini and palatopharyngeus in a morphologically normal transverse orientation. In the 7 patients in whom adequate velar activity could not be observed, it was not possible to reliably rate the position of the

TABLE III: VELAR THICKNESS IN MILLIMETERS AMONG STUDY PATIENTS, AGE AND GENDER MATCHED SUBTELNY NORMS,¹¹ AND AGE, GENDER AND DIAGNOSIS MATCHED PATIENTS FROM MAZAHERI ET AL¹²

Patient No.	Velar thickness	Subtelny norms (SD)	Mazaheri data (SD)
1	10	7.8 (0.3945)	6.09 (1.07)
2	11.5	7.4 (0.4637)	7.84 (1.27)
3	12	7.9 (0.563 1)	6.7 1 (0.87)
4	10	7.8 (0.3945)	7.14 (0.72)
5	10	7.8 (0.3945)	7.84 (1.27)
6	10	7.4 (0.4637)	7.14 (0.72)
7	8	7.8 (0.3945)	7.14 (0.72)
8	10	7.7 (0.4221)	7.32 (0.96)
9	15	7.7 (0.4221)	7.32 (0.96)
10	11	7.7 (0.422 1)	5.96 (0.54)
11			
12	13.5	8.8 (0.5612)	7.5 1 (0.99)
13	6	7.8 (0.3945)	7.14 (0.72)
14	10	7.8 (0.3945)	6.77 (1.07)
15			
16			
17	4.5	7.4 (0.4637)	6.77 (1.07)

SD: standard deviation

Data for patients 11, 15 and 16 were excluded because radiographic landmarks for measurement could not be clearly determined.

velar dimple. This may have been due to poor patient cooperation or to intrinsic velar hypomobility.

Velar Dimensions

In order to analyse the data meaningfully, the study patients were compared with two historical comparison groups. The validity of these comparisons was maximised by matching patients for age, gender and diagnosis (where appropriate). The two comparison groups consisted of Subtelny's norms for non-cleft subjects¹¹ and similar data on patients with cleft palate who had undergone non-Furlow palatoplasties reported by Mazaheri et al¹² that were obtained using Subtelny's technique of measuring velar dimensions.

Comparisons with the Subtelny norms¹¹ revealed that, although the mean postoperative velar length in the study patients was slightly less than that in the non-cleft subjects, this difference was not statistically significant. If it is assumed that the velum in an unrepaired cleft is shorter than normal, these findings suggest that the Furlow procedure does result in the attainment of near normal velar length, and that some lengthening of the velum probably occurs.

A comparative analysis with the data of Mazaheri et al¹² revealed no significant difference in velar length between the Furlow and non-Furlow palatoplasties. However, the trend was that the Furlow patients had slightly longer velums than the non-Furlow patients of the comparison study, suggesting but not proving that

the Furlow procedure may be more effective in lengthening the velum than other palatoplasty techniques.

Velar thickness in the study patients was significantly greater than that of both control groups, clearly revealing that the Furlow technique results in a velar thickness that is greater than normal as well as when compared with velar thickness following non-Furlow palatoplasty techniques.

The anatomic findings regarding velar dimensions have been corroborated by a recent study by D'Antonio et al¹³ that documented significantly greater postoperative velar length and thickness compared with preoperative velar dimensions in patients who had undergone the Furlow Z-plasty.

Functional Implications

The implications of velar lengthening and thickening for velopharyngeal function appear to be positive, provided certain caveats are recognized. From an anatomic perspective, a longer velum would lie closer to the posterior pharyngeal wall, which clearly provides a mechanical advantage in velopharyngeal closure. A recent report from D'Antonio et al¹⁴ suggests that velar lengthening following the Furlow Z-plasty in patients with submucous and repaired cleft palates has clinically useful effects in terms of improving velar function. However, equally important are other factors such as velar movement and velar stretch capacity.¹⁵⁻¹⁷ Whether and how the Furlow procedure affects these functional parameters is unknown. A known effect of any Z-plasty technique is that length is increased at the expense of lateral width. If the Furlow technique is employed for the primary closure of wide clefts, it seems logical that a greater degree of lateral tension will be created compared to non-Furlow methods. This can of course be mitigated by the use of lateral relaxing incisions. In these situations, the possible adverse effect of lateral tension on velar stretch capacity must be considered.

The creation of a thicker soft palate implies that the nasal aspect of the velum will be endowed with greater bulk and will also lie closer to the posterior pharyngeal wall. This would clearly be an anatomic advantage in velopharyngeal function in individuals with coronal or circular patterns of closure. It is noteworthy that the increase in thickness is due mainly to the overlap of the levator veli palatini and palatopharyngeus across the midline. Although this overlap is morphologically abnormal when referenced against normal velar anatomy,⁹ its functional benefits have recently been documented perceptually, endoscopically and aerodynamically by D'Antonio et al¹⁴ in terms of creating useful bulk and convexity along the nasal aspect of the velum for velopharyngeal closure, particularly in the region of the midline. In addition, the overlap also provides anatomic compensation for the disruption of the musculus uvulae

that inevitably occurs when the nasal limbs of the Z-plasty are raised and transposed.^{9,10}

Study Limitations

As this was a retrospective investigation of patients who had undergone primary palatoplasty as infants, no preoperative data on velar dimensions was available, therefore the ideal situation of direct comparisons of preoperative versus postoperative length and thickness did not exist. Furthermore, in order to examine the effect of the Furlow procedure against other techniques of palatoplasty, the study patients should ideally have been compared with age, gender and diagnosis matched patients operated on by the same surgeons using another technique of palatoplasty. Such data were also not available because of the retrospective nature of the study.

Future research should focus on investigating whether the differences in velar anatomy resulting from the Furlow Z-plasty versus other techniques of palatoplasty are clinically meaningful in terms of postoperative velopharyngeal function.

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REFERENCES

1. Furlow L T. Cleft palate repair by double opposing Z-plasty. *Plast Reconstr Surg* 1986; 78:724-34.
2. Randall P, LaRossa D, Solomon M, Cohen M. Experience with the Furlow double reversing Z-plasty for cleft palate repair. *Plast Reconstr Surg* 1986; 77:569-76.
3. Spauwen P H M, Goorhuis-Brouwer S M, Schutte H K. Cleft palate repair: Furlow versus von Langenback. *J Craniomaxillofac Surg* 1992; 20:18-29.
4. Chen P K T, Wu J T H, Chen Y R, Noordhoff M S. Correction of secondary velopharyngeal insufficiency in cleft palate patients with Furlow palatoplasty. *Plast Reconstr Surg* 1994; 94:933-41.
5. Brothers D B, Dalston R W, Peterson H D, Lawrence W T. Comparison of the Furlow double-opposing Z-palatoplasty with the Wardill-Kilner procedure for isolated clefts of the soft palate. *Plast Reconstr Surg* 1995; 95:969-77.
6. Hudson D A, Grobelaar A O, Fernandes D B, Lentin R. Treatment of velopharyngeal incompetence by the Furlow Z-plasty. *Ann Plast Surg* 1995; 34:23-6.
7. Chen P K T, Wu J, Hung K F, Chen Y R, Noordhoff M S. Surgical correction of submucous cleft palate with Furlow palatoplasty. *Plast Reconstr Surg* 1996; 97:1136-46.
8. McWilliams B J, Randall P, LaRossa D, Cohen S R, Yu J, Cohen M, et al. Speech characteristics associated with the Furlow palatoplasty as compared with other surgical techniques. *Plast Reconstr Surg* 1996; 98:610.
9. Huang M H S, Lee S T, Rajendran K. Anatomic basis of cleft palate and velopharyngeal surgery: implications from a fresh cadaveric study. *Plast Reconstr Surg* 1998; 101:613-27.
10. Huang M H S, Lee S T, Rajendran K. Structure of the musculus uvulae: functional and surgical implications of an anatomic study. *Cleft Palate Craniofac J* 1997; 34: 466-74.
11. Subtelny J D. A cephalometric study of the growth of the soft palate. *Plast Reconstr Surg* 1957; 19:49-62.
12. Mazaheri M, Krogman W M, Harding R L, Millard R T, Mehta S. Longitudinal analysis of growth of the soft palate and nasopharynx from six months to six years. *Cleft Palate J* 1977; 14:52-61.
13. D'Antonio L L, Riski J R, Zajac D, Patel S M, Herber S C, Hardesty R A, et al. Changes in anatomy and function of the velopharynx following Furlow Z-plasty for the treatment of VPI. Presented at the 54th Annual Meeting of the American Cleft Palate-Craniofacial Association, New Orleans, Louisiana, April 7 to 12, 1997, and at the 8th International Congress on Cleft Palate and Related Craniofacial Anomalies, Singapore, September 7 to 12, 1997.
14. D'Antonio L L, Folk S N, Patel S M, Herber S C, Hardesty R A. Indications and outcome of Furlow Z-plasty as treatment for velopharyngeal insufficiency. Presented at the 8th International Congress on Cleft Palate and Related Craniofacial Anomalies, Singapore, September 7 to 12, 1997.
15. Simpson R K, Austin A A. A cephalometric investigation of velar stretch. *Cleft Palate J* 1972; 9:341-51.
16. Mourino A P, Weinberg B. A cephalometric study of velar stretch in 8 and 10-year-old children. *Cleft Palate J* 1975; 12:417-35.
17. Simpson R K, Colton J. A cephalometric study of velar stretch in adolescent subjects. *Cleft Palate J* 1980; 17:40-7.