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# The Postoperative Speech Intelligibility Evaluation of Modified Z-Plasty Palatoplasty

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**Abstract:** The aim of the present study is to test the feasibility of modified Z-plasty palatoplasty for cleft palate repair in surgeries and provide a new surgical method. Forty cleft palate patients were selected as participants and divided into 2 groups in random. Twenty patients in the experiment group were treated by modified Z-plasty palatoplasty while the other 20 patients in the control group by double opposing Z-plasty and Sommerlad palatoplasty. By evaluating and observing postoperative velopharyngeal movement, speech intelligibility, nasal leaking, analysis of CSL (Computer Structure Language) and X-ray velopharyngeal lateral radiographs, Modified Z-plasty palatoplasty achieved better results than traditional operation. Satisfactory linguistic effects on incomplete cleft palate can be observed after modified Z-plasty palatoplasty treatment. So this method may be used as a clinical choice.

**Key Words:** Articulation, cephalometric lateral radiographs, cleft palate, modified Z-plasty palatoplasty for cleft palate repair, primary palatoplasty, velopharyngeal

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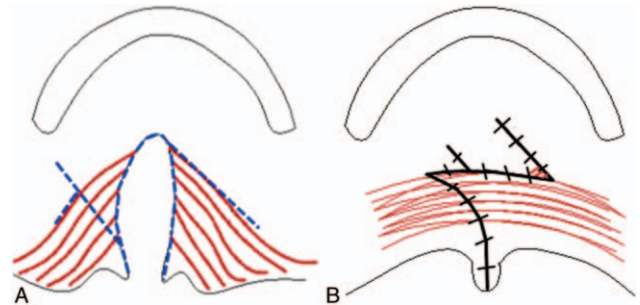
Speech restoration is an important index to evaluate the effects of cleft palate repair. The key of phonetic effects depends on functional recovery of the soft palate.<sup>1</sup> At present, palatotomy for incomplete cleft palate mainly refers to Furlow double opposing Z-plasty (DOZ) and levator veli palatini repositioning put forward by Sommerlad. Compared with traditional surgery, these therapies could improve patients' speech in some degree, but the treatment situation remains unsatisfactory. With existing therapies, 5% to 44% patients still suffer from velopharyngeal dysfunction.<sup>2</sup> Cleft palate speech characterized by compensatory articulation, such as high nasals, nasal air leakage, and nasal fricatives, is majorly caused by velopharyngeal

insufficiency (VPI) after palatotomy.<sup>3</sup> Therefore, it is necessary and important to develop an innovative surgical method for cleft palate patients.<sup>4</sup> Over the years, on the basis of conventional palatoplasty, we devised modified Z-plasty palatoplasty repair on nasal mucosal flap, correcting the trend of levator veli palatini and lengthening the soft palate with linear scars only on the oral mucosae. This study evaluated the effects of this new surgical method via comparison of postoperative velopharyngeal function.

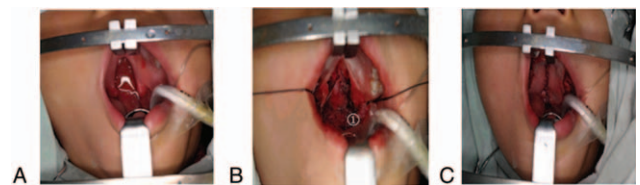
## METHODS

### Modified Z-Plasty Palatoplasty for Cleft Palate Repair

General anesthesia was given to the patients (Figs. 1 and 2). A dilute solution of lidocaine with epinephrine was infiltrated along the cleft margin and the lines of the palatal incisions to reduce bleeding during surgery. According to the von Langenbeck procedure, the mucosa along the edges of the cleft was incised. With this technique, relaxing incisions are made along the lateral edges of the palate, just medial to the alveolar ridge, and subsequent undermining is performed sufficiently to allow easy approximation in the midline of 2 separated mucoperiosteal flaps from the palatal bone and nasal mucosal edges on both the sides of the cleft. The undermining is performed between the bilateral oral mucosa and palatal muscles. As shown in Figure 1A and B, the muscle layer was exposed. First, a Z-plasty was drawn on the surface of the muscle. Then an additional



**FIGURE 1.** Schematic diagram of modified Z-plasty palatoplasty for cleft palate repair. ((A) The levator muscle bundle was attached to the nasal layer, and closed nasal layer was left intact while not dissected as in a traditional furlow Z-plasty. (B) Moving tissue flaps with suture make the broken ends close together).



**FIGURE 2.** Schematic diagram of modified Z-plasty palatoplasty for cleft palate repair (A) Before operation incision. (B) The oral mucosal flaps have been raised prior to commencing the muscle dissection and the muscle complex reconstruction. Note the 1 in the circle which denotes the levator muscle of palatine velum. (C) Sutured oral mucosa.

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incision was made on the lateral side of the velvolar levator muscle, which was in line with the direction of the muscle bundle (Fig. 1). After rotation and suture of flaps, the trend of muscle fibers of levator veli palatini becomes normal with opposite broken ends on both sides.

### General Clinical Data

Forty patients with nonsyndromic incomplete cleft palate aged 5 to 25 were included and all of them received treatment at the Stomatological Hospital of Zunyi Medical University between January, 2014 and September, 2015. The patients were comprised of 14 female patients and 26 male patients and the average age is 15.25 years old.

### Methods

According to specific conditions of each patient, different surgical methods were applied to them on the basis of morphology and function of their soft palates. Patients in group A received modified Z-plasty palatoplasty. In group B, 12 patients had DOZ, while 8 patients underwent Sommerlad palatoplasty. Patients’s velopharyngeal function and speech intelligibility were compared before and 3 months after operation.

### Test of Speech Intelligibility

Consonant articulation was figured out via quantitative evaluation (formula of consonant articulation: correct consonant syllables/total consonant syllables × 100%). The speech recovery was regarded to be good, when the outcome of the test ≥ 70%.<sup>5</sup>

### High Nasals

The evaluators assessment was categorized in 4 grades (grade 0—normal, 1—mild, 2—moderate, and 3—severe hypernasality) as proposed by an international working.<sup>6</sup>

Assessment Criteria of Nasal Air Leakage

We selected /i/ out of Chinese pinyin (Fig. 1).

Grade 0: when a subject pronounces /i/, there is no water vapor on the surface of a fog filter.

Grade 1: when a subject pronounces /i/, the length of water vapor on the surface of a fog filter is within 2 cm.

Grade 2: when a subject pronounces /i/, the length of water vapor on the surface of a fog filter is more than 2 cm.

### Lateral Cephalometric Pharyngeal Radiographs

Fixed points: A: the intersection point of the extended line of BC and the posterior pharyngeal wall; B: the still knee-point of nasal soft palate; and C: the knee-point of nasal soft palate during pronunciation of /i/.The length of AC, namely the depth of the pharyngeal cavity, was measured.

Evaluation criterion:<sup>4</sup> normal velopharyngeal closure: AC<4 mm; Incomplete velopharyngeal closure: AC≥4 mm.

### Voice Spectrum Analysis

The VS-99 Speech Workstation was applied to record the pronunciation of all subjects. In our special speech laboratory, subjects were required to pronounce/a/ and /i/ for recording on a single track with sampling frequency of 10,000 Hz, 16 units. Upper and lower limit values of frequency of first 3 resonance peaks (F1, F2, and F3) were detected and averaged as the resonance peak value of vowels. Speech analyses on pronunciation were carried out respectively before and after operation in the experimental and the control group. Statistical analyses of first 3 resonance peaks (F1, F2, and F3) of the 2 pure vowels were conducted with statistical software respectively (Fig. 3).

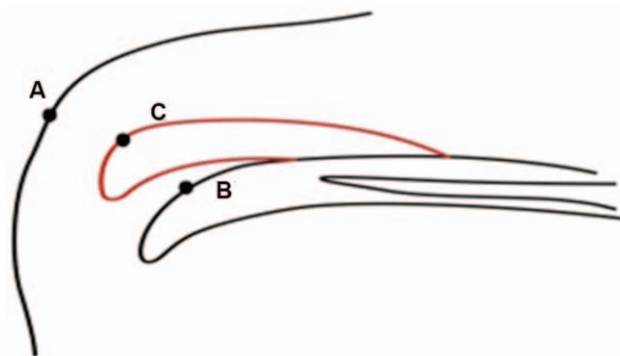


FIGURE 3. The sketch map of cephalometric landmarks.

## RESULTS

All surgical wounds of the 40 patients met the standard of clinical healing by first intention without perforation or infection of both soft and hard palates and no perforation or cleft relapse of suture was observed after operation.

### Evaluation of Speech Intelligibility

Patient evaluation was carried out according to the speech intelligibility evaluation sheet offered by the Stomatological Hospital of Zunyi Medical University. After operation, 85% patients in the experimental group showed speech intelligibility above 70%, while only 80% patients showed speech intelligibility above 70% in the control group, and the difference in the 2 groups was statistically significant ( $P < 0.05$ , Table 1).

### Evaluation of Nasal Resonance

After operation, compared with patients in the control group, more patients had normal or mild nasals in the experimental group with statistical significance ( $P < 0.05$ , Table 2).

With assessment of nasal air leakage by a fog filter, there were more patients of Grade 0 in the experimental group with statistical significance ( $P < 0.05$ , Table 3).

TABLE 1. Evaluation of Speech Intelligibility (Case [%])

Group	Articulate Patients Before Operation	Articulate Patients After Operation
Group A	5 (25.0%)	17 (85.0%)
Group B	6 (30.0%)	16 (80.0%)
$\chi^2$	0.625	4.286
$P$	0.429	0.038*

\* $P < 0.05$ .

TABLE 2. Evaluation of Postoperative Nasal Resonance (Case)

Group	Grade 0	Grade 1	Grade 2	Grade3	Z	P
Group A	13	4	2	1		
Group B	8	5	3	4	-2.331	0.02*

\* $P < 0.05$ .

**TABLE 3.** Assessment of Postoperative Nasal Air Leakage

Group	Grade 0	Grade 1	Grade 2	Z	P
Group A	10	8	2		
Group B	7	9	4	-2.434	0.015*

\*P < 0.05.

**TABLE 4.** Evaluation of Lateral Cephalometric Pharyngeal Radiographs (Case [%])

Group	Number of Patients of Normal Velopharyngeal Closure	Normal Rate (%)	P
Group A	17	85	0.022*
Group B	14	70	

\*P < 0.05.

In the experimental group, 17 patients had normal velopharyngeal closure with a postoperative normal velopharyngeal closure rate of 85%, while in the control group, there were 14 patients showing normal velopharyngeal closure with a postoperative rate of normal velopharyngeal closure of 70%. The distributional difference of comparison of postoperative X-ray films between the 2 groups was of statistical significance (P < 0.05) (Table 4).

**Voice Spectrum Analysis**

Through the VS-99 Speech Workstation, speech analyses on pronunciation of /a/ and /i/ before and after operation were carried out respectively (Tables 5 and 6). Resonance peak values of the first 3 resonance peaks (F1, F2, and F3) of the 2 pure vowels in experimental and control group were compared. Results showed that during pronunciation of /a/ and /i/, F1 of the 2 groups were similar (P > 0.05) and F2 and F3 showed significant difference (P < 0.05). Values in the experimental group were higher than those in the control group.

**DISCUSSION**

Most studies on velopharyngeal function merely focus on postoperative recovery of velopharyngeal closure and ignore the recovery

of coordination of velopharyngeal muscular movement. However, Velopharyngeal closure cannot reflect the velopharyngeal function completely.<sup>7</sup> In the clinical, though some patients show incomplete velopharyngeal closure, according to fibronasopharyngoscopy, they can form complete velopharyngeal closure when they pronounce certain sounds. These patients meet anatomical conditions of formation of complete velopharyngeal closure. Hence, surgeons tend to pursue recovery of anatomical structure of palatal muscles.<sup>8</sup> It is undeniable that the defects of the operation design can have a significant impact. For example, regarding Sommerlad palatoplasty, although it reconstructs levator veli palatini and enhances the effective length of a soft palate, it may also cause great damage to levator veli palatini and leave severe scars, which limits normal function of reconstructed levator veli palatini to some extent.<sup>9</sup> Meanwhile, with no extension of the soft palate on the nasal mucosal level, the surgery impacts postoperative velopharyngeal closure.<sup>10</sup> According to a comparative study on the soft palate and body muscles of rats, muscles of the head have fewer Satellite cells (SatCs) than muscles of limbs. So after the same crush or trauma, regeneration of muscles in the head is much slower, forming fibrous connective tissues.<sup>11</sup> Therefore, in soft palate surgery, muscle injury should be minimized. Otherwise, it would be difficult for the soft palate muscle to recover function. Considering the opposing Zs on the oral mucosa and the nasal mucosa in DOZ,<sup>12</sup> DOZ is not suitable for patients who suffer from complete cleft palate or require bilateral relief incisions. Because relief incisions could affect blood supply for mucosal flaps of a soft palate and the Z-shaped incision may cause extensive scars, leading to lengthening failure of the soft palate.<sup>13</sup> Excessive overlapping suture of levator veli palatini and the velopharyngeal muscle on the median line of a soft palate and the malposed uvularis after DOZ break the normal anatomical structure, forming asymmetric velopharyngeal closure and leading to insufficient rotation and displacement for nasal cleft sutures.<sup>8,14</sup> In modified Z-plasty palatoplasty, after cutting open edges of the soft palate, anatomy is conducted in amid mucous glands and muscles, which exposes muscles above the nasal mucosa completely. An incision is then made on the outer side of levator veli palatini near the free-end along the trend of its muscle fibers, intersecting the incision that cuts apart the muscle. As a result, the shape of the whole incision is like the Chinese character “之”. After rotation and suture of flaps, the trend of muscle fibers of levator veli palatini on both sides becomes normal with opposite broken ends. By this new operation method, the trend of levator veli palatini is

**TABLE 5.** Comparative Analysis of Resonance Peak Values of /i/ in the Experimental Group and the Control Group (Hz, x ± s)

Group	F1		F2		F3	
	Preoperative Value	Postoperative Value	Preoperative Value	Postoperative Value	Preoperative Value	Postoperative Value
Group A	355.75 ± 83.38	334.60 ± 62.74	1072.35 ± 641.14	1865.40 ± 847.38	1920.20 ± 947.37	2410.70 ± 908.90
Group B	354.20 ± 94.36	373.35 ± 74.04	1066.50 ± 551.18	1682.05 ± 916.57	1958.90 ± 852.57	2138.80 ± 982.35

**TABLE 6.** Comparative Analysis of Resonance Peak Values of /a/ in the Experimental Group and the Control Group (Hz, x ± s)

Group	F1		F2		F3	
	Preoperative Value	Postoperative Value	Preoperative Value	Postoperative Value	Preoperative Value	Postoperative Value
Group A	604.15 ± 348.36	659.30 ± 360.57	1198.05 ± 534.32	1720.45 ± 354.62	1766.95 ± 740.94	2464.10 ± 717.69
Group B	596.75 ± 220.73	599.35 ± 307.60	1133.20 ± 260.08	1689.70 ± 464.73	1996.50 ± 813.16	2058.95 ± 721.97

corrected without anatomy. Meanwhile, the soft palate on the level of the nasal cavity is lengthened and the pharyngeal cavity is shrunk, laying a good foundation for normal pronunciation in the future.

Postoperative speech and velopharyngeal function recovery are the important indexes of postoperative effect monitoring. Good velopharyngeal function is critical for good pronunciation.<sup>15</sup> Assessments on postoperative phonetic effects include subjective and objective assessments.<sup>16</sup> Subjective evaluation by professionals is still a gold standard for assessments of phonetic effects, while objective evaluation can confirm the results of subjective evaluation.<sup>16,17</sup>

In this study, through preoperative evaluation of speech intelligibility of cleft palate patients, it was found that all 40 patients showed certain high nasals, nasal air leakage, compensatory articulation, etc. By using the evaluation sheet of speech intelligibility offered by the Stomatological Hospital of Zunyi Medical University, patients in group A showed better speech intelligibility than those in group B after operation. In respect of nasal resonance and nasal air leakage, the group A also displayed better performance than group B, indicating the velopharyngeal function in group A was greatly improved after operation. X-ray lateral pharyngeal radiography can reflect velopharyngeal closure in some degree. The experiment results showed the velopharyngeal closure in group A was better compared with group B. Through the voice spectrum analysis, postoperative effects were evaluated objectively. According to the present study, the first 3 resonance peaks are of high significance for research on speech of cleft palate patients.<sup>18</sup> In this study, values of the first 3 resonance peaks of /a/ and /i/ were used as observation indexes and the results indicated that group A had better performance than group B in terms of improvement of tongue retraction and velopharyngeal function.

In conclusion, reconstruction of velar muscles is accomplished well in this method and the velar muscles are repositioned more transversely and posteriorly, which establishes an anatomic arrangement closer to the normal palate. This modified Z-plasty palatoplasty for cleft palate repair can become an optional surgical method for cleft palate clinically. Personalized therapies should be formulated in accordance with conditions of different patients to improve the postoperative velopharyngeal function. However, any improvement needs to be clinically tested. Although some elder patients with cleft palate obtained satisfactory phonetic effects and velopharyngeal function after modified Z-plasty palatoplasty, the long-term effect is still unknown, which requires larger sample research and long-term follow-up.

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