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Effect of palatoplasty technique on otologic outcomes in children with cleft palate

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ABSTRACT

Background: In patients with cleft palate (CP), the impact of primary palatoplasty technique on otologic outcomes remains a major point of contention. While some studies report improved outcomes after certain techniques of palatal repair, there is a lack of consensus on the most effective procedure.
Objective: We sought to characterize the effects of primary palatoplasty technique on otologic outcomes in children with CP.
Methods: A single institution retrospective review of patients with CP who underwent primary palatoplasty (straight-line repair or Furlow Z-plasty) was performed. Primary outcomes of interest included time to placement of T-tubes, number of tympanostomy tube placements, tympanic membrane (TM) perforation, and 3-year and 6-year postoperative hearing thresholds.
Results: A total of 140 patients were included in this study. The mean number of tympanostomy tube placements in the straight-line repair group (1.93 ± 1.28) was significantly higher than in the Furlow Z-plasty group (1.42 ± 1.03, $p = 0.03$). Median time from primary palate repair to T-tube placement was 38.93 (IQR 33.03) months. Higher birth weight ($p < 0.01$) and multiple tympanostomy tube placements ($p < 0.05$) were associated with longer time to T-tube placement. T-tube replacement was associated with a 16.9 times higher likelihood of TM perforation ($p < 0.05$). The median PTA significantly improved from 16.25 (IQR 7) dB at 3 years to 11.00 (IQR 5.25) dB at 6 years ($p < 0.01$).
Conclusions: Furlow palatoplasty technique was associated with fewer number of tympanostomy tube placements; however, palatoplasty technique did not significantly impact time to T-tube placement, TM perforation, or hearing outcomes. There were no significant differences in long-term hearing outcomes between patients who underwent Furlow Z-plasty and those who had straight-line repair. Most patients achieved normal hearing thresholds by 6 years after primary palatoplasty and tympanostomy tube placement. These are important considerations to discuss when counseling patients' families on surgical management of CP and otologic outcomes.

1. Introduction

Cleft palate (CP) with or without cleft lip is among the most prevalent craniofacial birth defects in the world and has a variety of consequences in children, including facial deformities, dental abnormalities, speech difficulties, and hearing loss. Since the association between CP and hearing impairment was first identified in 1878, eustachian tube dysfunction (ETD) and subsequent otitis media with effusion (OME) continue to be universally reported in patients with CP [1,2]. Although multifactorial, the pathogenesis of these complications is largely related to the displacement of palatal musculature. The palatal muscles, tensor and levator veli palatini, are responsible for soft palate elevation, velopharyngeal closure, and dilation of the eustachian tube. In patients with CP, abnormal insertion of the palatal muscles due to the absence of palatal fusion results in impaired dilatation of the eustachian tube and persistent middle ear effusion[3]. Without intervention, persistent middle

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ear effusion causes a conductive hearing loss (CHL) that ultimately affects speech and language development.

A significant number of children with CP continue to have persistent or recurrent OME throughout childhood, even after palate repair [2,3]. To prevent chronic OME and associated hearing loss, patients with CP routinely have tympanostomy tubes placed at the time of either cleft lip or palate repair. While standard short-term tubes are most commonly placed, Goode or Richards T-tubes serve as a longer-term option and require fewer tube replacements. However, risk of tympanic membrane (TM) perforation and cholesteatoma are reported to be higher after T-tube placement than with standard short-term tubes [4]. This suggests a need for caution in the use of T-tubes in the cleft population.

There are many factors related to palatal repair that impact ETD and middle ear outcomes, with the technique of palatoplasty being a major point of contention. The von Langenbeck palatoplasty technique, first described in 1861, involves straight-line closure of the palatal cleft without lengthening the soft palate. The two-flap palatoplasty technique is a variant of the von Langenbeck that incorporates soft palate lengthening [5]. The Furlow technique, designed in 1986, differs from the straight-line repair techniques due to the degree of palatal muscle dissection and realignment [6]. This technique describes double-opposing Z-plasties performed on the oral and nasal mucosa, which increases the muscular bulk of the posterior palate and lengthens the palate without pushback [7]. While several studies report improved otologic outcomes after palatoplasty, there is a lack of consensus on the most effective palatoplasty technique [8–10].

The purpose of our study is to further characterize the effects of palatal closure technique on otologic outcomes in children with CP. Similar to what some studies have reported, we hypothesized that the Furlow palatoplasty technique would yield more favorable otologic outcomes than the straight-line repair technique [6,7,10].

2. Methods

2.1. Design

A retrospective medical record review of patients who underwent primary palatoplasty at a tertiary pediatric hospital was performed. Following institutional review board (IRB) approval (HSC-MS-19-0161), the Current Procedural Terminology (CPT) code 42200 (palatoplasty for CP, soft and/or hard palate only) was used to identify all patients who underwent primary CP repair from 2007 to 2017. All patients were treated by the Texas Cleft/Craniofacial Team (TCCT) at the McGovern Medical School at UTHealth Houston. The TCCT has been continuously certified as a cleft team by the American Cleft Palate Association and provides multidisciplinary team care to patients with cleft lip and or CP.

Patients who had follow-up with our interdisciplinary team (pediatric otolaryngologists, pediatric plastic and reconstructive surgeons, audiologists) along with adequate documentation of surgical management, audiograms, and postoperative complications were included. Patients lost to follow-up as well as those with sensorineural hearing loss, ossicular chain abnormalities, and other congenital ear malformations were excluded. Patient demographics, Veau class, medical history, surgical management, and audiograms were collected. Patients were divided into two cohorts based on the type of primary CP repair they received: straight-line or Furlow palatoplasty. The primary outcome was the time from primary palatoplasty to placement of a long-term T tube. The secondary outcomes included the number of tympanostomy tubes (both standard short-term and long-term T-tubes) placed, TM perforation, and postoperative 3-year and 6-year hearing thresholds, further defined below. Clinical data, including otologic outcomes, was collected through October 2023.

2.2. Surgical management

Primary CP repair techniques were categorized into two groups: straight-line repair and Furlow Z-plasty. Palatoplasties were performed by three pediatric plastic surgeons at the same tertiary pediatric hospital. The type of palatoplasty performed was based on the surgeon's clinical decision and not randomized. Tympanostomy tube placements were performed by one of five pediatric otolaryngologists at the same institution. The tympanostomy tubes that were placed included both standard short-term tubes and long-term T-tubes. Both types of ventilation tubes were counted in the total number of tympanostomy tubes placed in a patient. Many patients had concurrent short-term tympanostomy tubes placed at time of palate repair due to the high prevalence of otitis media observed in the first few months of life. The tubes placed concurrently at time of palate repair were not counted in the total number of tympanostomy tube placements. Postoperatively, patients had close follow-up with our institution's multidisciplinary team with continued monitoring for middle ear disease. Tympanostomy tubes were replaced as needed for patients who continued to demonstrate conductive hearing loss, recurrent acute otitis media, or chronic OME.

2.3. Audiologic measures

Hearing outcomes were characterized using pure-tone average (PTA) scores, with normal hearing threshold defined as a PTA score $\leq$ 20 dB (dB). Audiograms at 3-year and 6-year postoperative follow-ups were performed by our institution's audiologists. PTA scores were calculated based on averages of the left and right ear hearing thresholds at 0.5 kHz, 1 kHz, and 2 kHz in air or sound field.

2.4. Statistical analysis

Multivariate linear regressions were performed to determine factors that impact time to T-tube placement and postoperative hearing outcomes. Multivariate logistic regression was performed to determine the risk factors for TM perforation. Time-to-event analysis (survival analysis) was used to determine Kaplan-Meier curves for time to TM perforation along with Cox proportional hazard regression between different palatoplasty techniques. Fisher's exact test was used to determine significance of association between palatoplasty technique and categorical demographic variables including T-tube placement, sex, Veau class, and genetic syndrome. Mann-Whitney *U* test was used to determine significance of association between palatoplasty technique and nominal variables including number of tympanostomy tube placements, time to TM perforation, age of primary palate repair, birth weight, and 3-year and 6-year post-operative hearing thresholds. Wilcoxon signed-rank test was used to compare PTA scores at 3-year and 6-year follow ups. A *P* value $<$0.05 was used for significance level. All analysis was conducted using Stata statistical software (StataCorp LLC, College Station, TX, last updated 2024).

3. Results

3.1. Demographics

There were 316 children with CP that were reviewed for the study, of which 140 met the inclusion criteria (Fig. 1). Of these patients, 70 (50 %) were female, and 70 (50 %) were male. Ninety-seven (69.29 %) patients underwent straight-line repair, and 43 (30.71 %) patients underwent Furlow Z-plasty. Primary straight-line repair and Furlow Z-plasty were performed at a median age of 12.5 (IQR 2.54) months and 12.9 (IQR 2.71) months, respectively. Fifteen patients (10.71 %) had a co-existing genetic diagnosis or syndrome that didn't involve congenital ear malformation or ossicular chain abnormalities (Table 1*)*. The incidence of genetic syndromes was significantly higher in the Furlow Z-plasty group compared to the straight-line repair group (25.58 % vs 4.12 %, $p < 0.01$). Of these patients, five have isolated Pierre-Robin Sequence, two have Stickler syndrome, and one patient each have Kabuki syndrome, Van Der Woude syndrome, PHACE syndrome, and

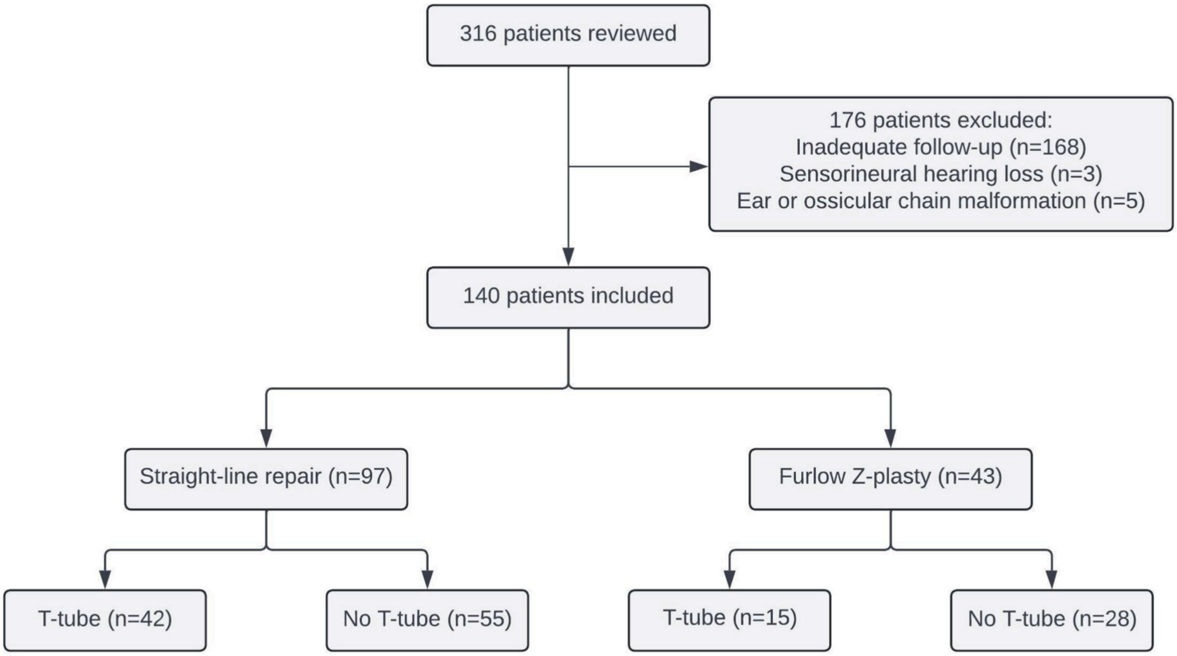

Fig. 1. Study Flow Diagram.

Table 1
Patient Demographics Stratified by Primary Palatoplasty Technique.

Demographic	Furlow	Straight-line	*P* value
Sex			0.14[a]
Male, n	17	53	
Female, n	26	44	
Veau class			0.02[a]
Submucous CP, n	2	1	
Veau I, n	9	5	
Veau II, n	5	23	
Veau III, n	19	48	
Veau IV, n	8	20	
Genetic syndrome, n	11	4	<0.01[a]
Median age at palatoplasty, mo (IQR)	12.9 (2.71)	12.5 (2.54)	0.16[b]
Median birth weight, kg (IQR)	2.91 (0.65)	3.18 (0.96)	0.21[b]

Abbreviations: CP = cleft palate, n = number of patients, mo = months, kg = kilograms, IQR = interquartile range.
[a] Fisher's exact test.
[b] Mann-Whitney *U* test.

Table 2
Otologic Outcomes Stratified by Palatoplasty Technique.

Outcome	Furlow	Straight-line	All	*P* value
Median months to T-tube placement (IQR)	24.36 (34.53)	41.25 (29.23)	38.93 (33.03)	0.34[a]
T-tube placement, n	15	42	57	0.456[b]
>1 T-tube placement, n	2	11	13	0.844[b]
Mean tympanostomy tube placements[x]	1.42 ± 1.03	1.93 ± 1.28	1.77 ± 1.23	0.03[c]
TM perforation, n	9	16	25	0.90[a]
Median months to TM perforation (IQR)	67.73 (23.97)	50.52 (23.83)	57.37 (27.27)	0.20[c]

Abbreviations: n = number of patients, IQR = interquartile range, TM = tympanic membrane.
[x] Includes grommet and long-term T-tubes placed after primary palatoplasty.
[a] Multivariate regression analysis.
[b] Fisher's exact test.
[c] Mann-Whitney U test.

DiGeorge syndrome. The other four patients have genetic anomalies officially diagnosed by a geneticist.

3.2. Tympanostomy tubes

The median time from primary CP repair to T-tube placement was 38.93 (IQR 33.03) months (Table 2). Although the median time to T-tube placement following Furlow Z-plasty (24.36 months, IQR 34.53) was less than that of straight-line repair (41.25 months, IQR 29.23), palatoplasty technique was not significantly associated with time to T-tube placement ($p = 0.34$). Palatoplasty technique was also not significantly associated with T-tube placement ($p = 0.456$) or multiple T-tube placement ($p = 0.844$) outcomes. There was a significant difference in the mean number of tympanostomy tube placements after straight-line repair (1.93 ± 1.28) and Furlow Z-plasty (1.42 ± 1.03) over the 6-year postoperative time frame ($p = 0.03$) (Table 2). On multivariate analysis, higher birth weight ($p < 0.01$) and multiple tympanostomy tube placements ($p < 0.05$) were significantly associated with longer time to T-tube placement (Table 3). Additionally, sex, syndrome diagnosis, age at primary CP repair, and Veau class did not show significant association with time to T-tube placement (Table 3).

3.3. Tympanic membrane perforations

TM perforation occurred in 9 patients (20.93 %) who underwent Furlow Z-plasty and 16 patients (16.49 %) who had straight-line repair ($p = 0.90$). There were no significant associations between outcome of TM perforation and palatoplasty technique, sex, birth weight, syndrome diagnosis, age of primary CP repair, and Veau class *(*Table 3*)*. Patients who underwent straight-line repair had a shorter median time to TM perforation (50.52 months, IQR 23.83) compared to patients who underwent Furlow Z-plasty (67.73 months, IQR 23.97), though the difference was not statistically significant ($p = 0.20$) (Table 2). Interestingly, Kaplan-Meier time-to-event curve for TM perforation suggests a 0.65 hazard ratio associated with the straight-line repair group compared to the Furlow Z-plasty group, however results were not

Table 3
Multivariate Linear Regression of Predictors of Time to T-tube Placement.

Variable	Coefficient [95%CI]	*P* value
Sex	1.62 [−8.74, 11.97]	0.75
Birth weight	0.01 [0.00, 0.02]	0.00
Syndrome diagnosis	−11.31 [−36.41, 13.77]	0.37
Age at primary palatoplasty	0.05 [−2.58, 2.69]	0.97
Palatoplasty technique[a]	−5.86 [−18.12, 6.39]	0.34
Veau class		
I[b]		–
II	−14.63 [−32.95, 3.70]	0.11
III	−14.03 [−30.03, 1.97]	0.08
IV	−7.41 [−23.98, 9.16]	0.37
No. of Prior Tympanostomy Tubes		
0[c]	–	–
1	5.29 [−6.47, 17.05]	0.37
2	18.61 [2.48, 34.74]	0.03
3	29.77 [13.08, 46.46]	0.00

Abbreviations: CI = confidence interval, No. = number.
[a] Furlow Z-plasty was used as the reference variable that was compared with straight-line repair.
[b] Veau class I was used as the reference variable that was compared with the other Veau classes.
[c] Group with 0 prior tympanostomy tubes was used as the reference variable that was compared with groups with ≥1 prior tympanostomy tubes.

Table 4
Multivariate Logistic Regression of Tympanic Membrane Perforation Risk Factors.

Variable	Odds Ratio [95%CI]	*P* value
Sex	0.93 [0.24, 3.65]	0.92
Birth weight	1.00 [1.00, 1.00]	0.31
Syndrome diagnosis	0.11 [0.00, 3.34]	0.21
Age at primary palatoplasty	1.12 [0.96, 1.30]	0.14
Palatoplasty technique[a]	1.11 [0.22, 5.68]	0.90
Veau class		
I	0.37 [0.00, 94.47]	0.73
II	0.27 [0.00, 79.70]	0.66
III	0.11 [0.00, 29.53]	0.44
IV	0.24 [0.00, 70.04]	0.62
No. of T-tubes		
1	2.06 [0.48, 8.80]	0.33
2	16.91 [2.15, 132.92]	<0.05
No. of Prior Tympanostomy Tubes		
1	18.99 [0.25, 1466.60]	0.18
2	8.71 [0.11, 684.82]	0.33
3	4.98 [0.06, 450.55]	0.49
4	6.18 [0.05, 697.82]	0.45

Abbreviations: CI = confidence interval, No. = number.
[a] Furlow Z-plasty was used as the reference variable that was compared with straight-line repair.

statistically significant ($p = 0.30$) (Fig. 2). Replacement of a T-tube was associated with a 16.9 times higher likelihood of TM perforation ($p < 0.05$) (Table 4).

3.4. Hearing outcomes

Of 140 patients, 73 (52.14 %) patients completed 3-year postoperative audiogram and 84 (60 %) patients completed 6-year postoperative audiogram (Table 5). Forty-seven (33.57 %) patients completed both 3-year and 6-year audiograms. At 3-year postoperative follow-up, 58 (79.45 %) patients met the normal hearing threshold of PTA ≤ 20 dB. At 6-year postoperative follow up, 75 (89.29 %) patients met the normal hearing threshold. The median PTA significantly improved from 16.25 (IQR 7) dB at 3 years to 11.00 (IQR 5.25) dB at 6 years ($p < 0.01$). The median PTA at 3-year follow-up was 16.25 (IQR 4.88) dB for patients who had Furlow Z-plasty and 16.25 (IQR 8.13) dB for patients who had straight-line repair ($p = 0.758$). The median PTA at 6-year follow-up was 12.50 (IQR 4.75) dB for the Furlow Z-plasty group and 11.00 (IQR 5.00) dB for the straight-line repair group ($p = 0.444$) (Table 5). On multivariate analysis, there were no significant associations between palatoplasty technique and PTA at 3 years ($p = 0.827$) or 6 years ($p = 0.390$). Older age at primary CP repair ($p < 0.01$) and higher Veau class ($p < 0.01$) were significant predictors of worse long-term hearing.

4. Discussion

The impact that palatoplasty technique has on otologic outcomes continues to be a source of controversy, especially because not all studies agree that there is a significant association [11]. We conducted a

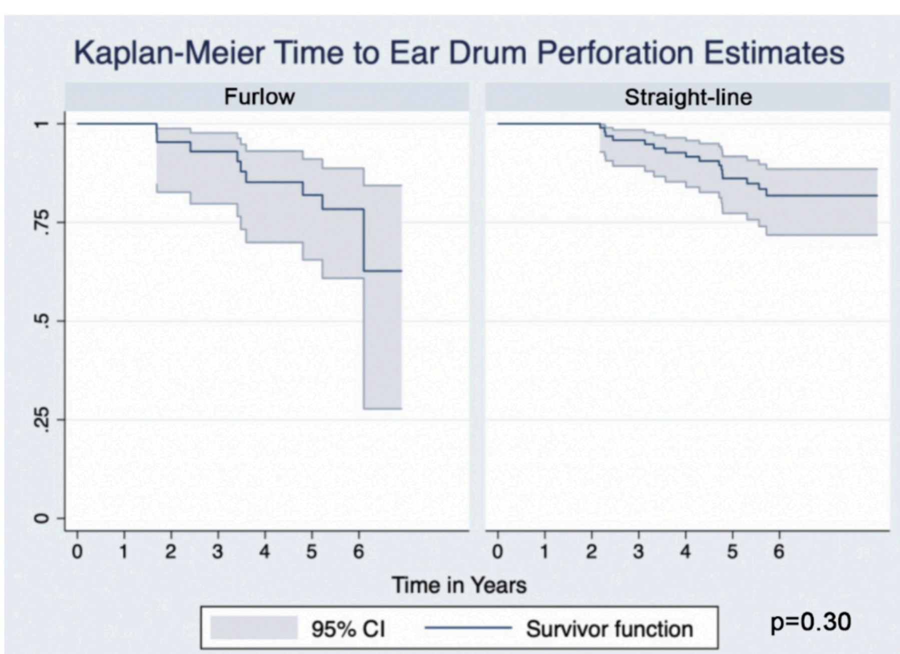

Fig. 2. Kaplan–Meier Time-to-Event Curve for Tympanic Membrane Perforation by Palate Repair Type.

Table 5
3-Year and 6-Year Postoperative Median PTA by Palatoplasty Technique.

Postoperative PTA	Furlow	Straight-Line	All	*P*
3-year median PTA, dB (IQR)	16.25 (4.88) ($n = 22$)	16.25 (8.13) ($n = 51$)	16.25 (7.00) ($n = 73$)	0.758[a]
6-year median PTA, dB (IQR)	12.50 (4.75) ($n = 19$)	11.00 (5.00) ($n = 65$)	11.0 (5.13) ($n = 84$)	0.444[a]

Abbreviations: PTA = pure-tone average, dB = decibel, IQR = interquartile range.
[a] Mann-Whitney *U* test.

retrospective review to further characterize the effects of palatal closure techniques on otologic outcomes in patients with CP, including time to T-tube placement, total number of tympanostomy tube placements, TM perforation, and 3-year and 6-year postoperative hearing thresholds.

Unlike some previous studies, our study suggests that palatoplasty technique may not have as much of an impact as previously thought [6,7]. To our knowledge, time to long-term T-tube placement is an otologic outcome that has not been previously studied in relation to palatoplasty technique. We did not observe a significant association between palatoplasty technique and time to T-tube placement. Notably, significant factors associated with increased time to T-tube placement were higher birth weight and multiple tympanostomy tube placements.

In our study, patients who had straight-line repair had a significantly higher number of tympanostomy tube insertions than patients who received the Furlow Z-plasty. This supports the findings previously reported by Kitaya et al. and Smith et al. [6,12]. The re-orientation of the palatal musculature with the Furlow Z-plasty technique is thought to improve eustachian tube function [13]. Since the Furlow technique allows for increased expansion of the soft palate compared to straight-line repair, it provides better nasopharyngeal closure to protect from nasopharyngeal reflux. The improved nasopharyngeal reflux and eustachian tube function decrease the frequency and severity of OME, which results in a decreased necessity for tympanostomy tube placements [12,14].

The median months from primary palatoplasty to TM perforation was 57.37 (IQR 27.27). Although the straight-line repair group had a shorter median time to TM perforation than the Furlow Z-plasty group, palatoplasty technique was not significantly associated with TM perforation outcome. Our findings differ from those of Kitaya et al., who reported a significantly higher rate of TM perforation in two-flap palatoplasty group compared to Furlow Z-plasty group [12]. Interestingly, our Kaplan-Meier curve suggested a 35 % lower risk of TM perforation in patients with straight-line repair compared to Furlow Z-plasty, but this did not account for other multivariate factors and was also not statistically significant.

Our multivariate regression analysis showed multiple T-tube placements as a significant risk factor for TM perforation. In a 20-year follow-up study of a randomized controlled trial that examined the long-term effects of T-tube placement in patients with CP, 5 of 7 patients continued to suffer symptoms of TM perforation, cholesteatoma, and chronic otitis media in the treated ear [15]. In our study, replacement of T-tube was associated with a 16.9 times higher likelihood of TM perforation ($p < 0.05$), which supports the previously reported association that long-term T-tubes increase the relative risk of TM perforation [4]. Unlike what Kitaya et al. suggested, however, multiple tympanostomy tube placements prior to T-tube placement was not a significant risk factor for TM perforation in our study [12]. The difference in risk of TM perforation between multiple placements of standard short-term tubes and long-term T-tubes may be due to the difference in duration of tube placement and physiological effects on the TM. T-tubes have flanges that anchor to the TM more securely to allow for longer placement duration, but this can subsequently cause mechanical stress and irritation over time. Multiple T-tube placements can induce chronic inflammation which can compromise TM healing and increase the risk of chronic TM perforation.

Since our analysis did not specify the laterality of the affected ear, it cannot be assumed that the TM perforations observed in our study are necessarily sequelae of long-term T-tubes. In our study, some of the patients with TM perforation suffered from persistent ETD or recurrent OME that necessitated further surgical intervention in the non-perforated ear. For these patients, an ear exam was done on the perforated side, while T-tube placement was done on the non-perforated side. Typically, the non-perforated ear demonstrated signs of poor ETD with persistent retraction and chronic effusion. Although TM perforation is often considered a complication, it may serve a similar functional benefit that ventilation tubes provide in this high-risk population.

Smith et al. reported that 92.5 % of patients with CP met normal hearing thresholds after tympanostomy tube placement [8]. The rate of patients that achieved normal hearing outcomes was similar in our study, which showed 58 patients (79.45 %) with normal hearing thresholds at 3-year follow-up and 75 patients (89.29 %) with normal hearing thresholds at 6-year follow-up. The significant improvement in hearing outcomes from 3-year follow-up to 6-year follow-up suggested that patients' hearing continued to improve over time even after normal thresholds were reached. Like several other studies, we did not observe a significant association between palatoplasty technique and hearing outcomes at 3 or 6 years [9,11,12]. In our study, the long-term hearing outcomes were similar between patients who underwent Furlow Z-plasty and those who had straight-line repair. As suggested by Smith et al., tympanostomy tube placement may prevent or lessen audiologic sequelae in patients with CP as early as immediately after placement [8].

The association between Veau class and middle ear status continues to be debated. While some studies suggest an association between Veau class and multiple tympanostomy tube placements, other studies did not observe this [16–19]. Our study did not show significant association between Veau class and number of tympanostomy tube placements. However, Veau class may impact the surgeon's choice of palatoplasty technique and had a significant impact on long-term hearing outcomes. Patients with a Veau classification of 1–4 had significantly worse long-term hearing outcomes than patients with a submucous cleft palate, likely due to the extent of cleft and palatal muscle disruption affecting the severity of ETD and impacting otologic outcomes.

Palatal surgery alone, without adequate surgical management of middle ear disease, only marginally reduces the incidence of OME in patients with CP [3]. Thus, the hearing outcomes in our study may also be attributed to patient compliance with the routine multidisciplinary follow up schedule that allowed for constant screening and management of middle ear disease. There may be a component of selection bias, as patients included in the hearing analysis were generally compliant with follow-up and completed postoperative audiograms and patients who were lost to follow-up were excluded. Compliant patients allowed for necessary treatment of OME and ETD with tympanostomy tube placements as deemed fit. In conclusion, a close liaison between the multidisciplinary units of plastic surgery, otolaryngology, and audiology must be present to allow for satisfactory management of otologic outcomes in patients with CP.

One major limitation in our study is the number of patients with inadequate follow-up. This limited the sample size of patients in our analysis. With less patients included in the analysis, there was a comparative paucity of patients in the Furlow Z-plasty group. This ultimately limited the power of our study. Although some of our analysis favored Furlow Z-plasty in some metrics, such as decreased number of T-tube placements, many of these findings were statistically insignificant. However, the large percentage difference in affected patients between the two cohorts for various metrics could likely show significant differences with a larger sample size. Hearing outcomes analysis was also limited as only 47 patients were able to complete both 3-year and 6-year postoperative audiograms. Furthermore, our study did not examine otologic outcomes by individual ears, which limited our sample size and analysis on otologic outcomes. Without this clarification, we were not able to specify the ear laterality of TM perforation or T-tube placement. Future directions could include a prospective study with patients randomized to palatoplasty repair groups that examines otologic outcomes of individual ears with specified laterality. With a larger sample size, rarer complications can be better studied. Finally, variation of surgical technique remains a limitation as these may include varying degrees of intervention on the tensor tendon, which can impact eustachian tube function and otologic outcomes.

Our study suggests that the otologic outcomes in children who underwent straight-line repair were not significantly different than those who had Furlow Z-plasty. In fact, palatoplasty technique did not significantly impact any of the metrics analyzed in our study. Increased birth weight and a higher number of previous tympanostomy tube placements were associated with a longer time to T-tube placement. Multiple T-tube placements increased the odds of TM perforation. After primary CP repair and tympanostomy tube placement, most patients reached normal hearing thresholds within 3 years, and hearing continued to significantly improve over time. These are important considerations to discuss when counseling patients' families on surgical management of CP and otologic outcomes.

5. Conclusion

Most of the otologic outcomes examined in this study did not favor a particular palatoplasty technique for primary palate repair. However, Furlow Z-plasty may yield a slight reduction in total tympanostomy tube placements. There were no significant differences in long-term hearing outcomes between patients who underwent Furlow Z-plasty and those who had straight-line repair. Most patients reached normal hearing thresholds within 3 years, and hearing continued to significantly improve over time. We recommend patient compliance with routine multidisciplinary follow up to allow for appropriate screening and management of middle ear disease. This information should be considered when counseling patients' families on surgical management of CP and otologic outcomes.

CRediT authorship contribution statement

Shaina W. Gong: Visualization, Writing – original draft. **Paul Hung:** Investigation, Visualization, Writing – review & editing. **Chioma G. Obinero:** Visualization, Writing – review & editing. **Jose Barrera:** Investigation. **Zi Yang Jiang:** Formal analysis, Visualization. **Matthew R. Greives:** Supervision, Visualization, Writing – review & editing. **Zhen Huang:** Conceptualization, Project administration, Writing – review & editing.

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Declaration of competing interest

No conflicts of interest.

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