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Submucosal Lingualplasty for Adult Obstructive Sleep Apnea

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Sponsorships or competing interests that may be relevant to content are disclosed at the end of this article.

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Abstract

Objective. To measure quality-of-life outcomes, polysomnographic outcomes, and adverse effects for a new technique of tongue reduction in obstructive sleep apnea.

Study Design. Case series.

Setting. Tertiary hospital.

Subjects and Methods. Consecutively treated adult patients (N = 27) with obstructive sleep apnea having submucosal lingualplasty in 2007 were studied. All had concurrent or previous uvulopalatoplasty ± palatal advancement. Full polysomnography preoperatively and 3.7 ± 0.4 months postoperatively, scored using the American Academy of Sleep Medicine 2007 criteria, was recorded. Snoring severity score, Epworth Sleepiness Scale, and complication data were collected at a 2.61 ± 0.08-year follow-up via questionnaire.

Results. Mean snoring severity score fell from 7.1 ± 0.4 to 2.3 ± 0.6 ($P < .05$). Epworth Sleepiness Scale score fell from 8.3 ± 1.1 to 5.8 ± 1.0 ($P < .05$). The apnea-hypopnea index (AHI) fell from 44.0 ± 4.3 to 12.5 ± 2.3 ($P < .05$). Success, defined as achieving an AHI <15 postoperatively, was observed in 74% (20/27), with each of these patients achieving a reduction in AHI >50%. Lowest oxygen saturation improved from 84 ± 1 to 88 ± 1 ($P < .05$). Pain was mild to moderate. Short-term postoperative complications included bleeding (3.7%) and infection (14.8%). Some minor long-term (6 months) alteration in tongue function was reported with regard to speech (47%), swallow (33%), and taste (33%).

Conclusion. Submucosal lingualplasty with concurrent palatal surgery is a promising treatment option in adult patients with obstructive sleep apnea with macroglossia.

Keywords

obstructive sleep apnea, submucosal lingualplasty, sleep, sleep study, sleep surgery, tongue reduction surgery

Adult obstructive sleep apnea (OSA) may be treated conservatively, with continuous positive airway pressure therapy, mandibular advancement splints, or upper airway surgery.[1] Patients with retrolingual collapse require surgical therapy directed to this segment of the upper airway, as the results of isolated palatal surgery in this group are poor.[2] The principal causes of anteroposterior retrolingual collapse are hypotonia, macroglossia, lingual tonsil hypertrophy, or retrognathia, either alone or, more commonly, in combination.[3] Although multiple options exist to tension a hypotonic tongue, no contemporary upper airway reconstructive technique has yet gained widespread acceptance into routine surgical practice for low-morbidity effective reduction of macroglossia.

Radiofrequency ablation has shown promise as a technique with low morbidity; however, it is limited by low efficacy and need for multiple treatments.[4] Mucosal sacrificing midline glossectomy has yielded 50% response rates.[4] Extension of mucosal sacrificing tongue reduction from between the neurovascular bundles (midline glossectomy) to include some lateral tongue excision (lingualplasty), either transoral or external, has yielded 80% response rates in

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Table 1. Patient Demographics

Total number of patients	27
Male sex, No.	22
Age, y, mean ± SD	50.7 ± 2.1
BMI	30 ± 1
SML primary tongue procedure, No.	16/27
Concurrent surgery UPPP + PA	16/16
SML salvage procedure, No.	11/27
Tongue size, No.	
Friedman 2	8
Friedman 3	14
Not recorded	5

Table 1 shows a larger number of patients undergoing SML as a primary tongue procedure concurrent with UPPP and PA. The SML salvage procedure was performed in those who had undergone 1 or a combination of UPPP, a PA, coblation tongue base channeling, hyoid suspension, or genial tubercle advancement. Abbreviations: BMI, body mass index; PA, palatal advancement; SML, submucosal lingualplasty; UPPP, uvulopalatopharyngoplasty.

severe OSA with macroglossia but with high morbidity.[5,6] Similarly, maxillomandibular advancement (MMA) effectively increases the space in macroglossia; however, patient acceptance is limited. Therefore, MMA is reserved as a salvage option.[7]

Mucosal-sparing glossectomy techniques have evolved over the past decade.[3,8] Postoperative pain has been noted to be less than mucosal sacrificing techniques. Although the technique of submucosal lingualplasty (SML) has been described previously,[8] outcomes and safety data have not yet been reported in the literature.

Methods

Patients

Consecutively treated adult patients with OSA having SML during 2007 from a single surgeon's practice were studied. All cases had a patent nasal airway documented preoperatively. Cases with previous midline tongue reduction surgery were excluded, leaving 27 SML cases. Macroglossia was defined by 2 or more of the following 3 criteria: clinical findings of a Friedman oral tongue size 3 (or 4), moderate or severe endoscopic macroglossia (obscuring at least part of the view of the vocal cords in supine mid-respiration awake examination), and a mid-sagittal area of >26 cm^2 on spiral computed tomography (CT) scan, which defines greater than average tongue size for adult OSA.[9,10] Combined retropalatal and retrolingual upper airway obstruction (ie, Fujita type 2 pathophysiology) was demonstrated in all patients at initial assessment by awake nasendoscopy (including supine Woodson's hypotonic method and supine Müller maneuver) and sedation nasendoscopy (if awake assessment was indeterminate).[11] To manage retropalatal collapse, concurrent or previous uvulopalatopharyngoplasty (UPPP) ± palatal advancement (PA) was performed on all patients (**Table 1**). Fifty-nine percent of patients had no history of previous tongue surgery, whereas 41% had SML for salvage surgery after an inadequate response to previous UPPP, PA, geniotubercle advancement, hyoid suspension, radiofrequency ablation, or lingual tonsillectomy (either alone or in combination) (**Table 1**).

Surgery

Submucosal lingualplasty was performed under general anesthesia, using Coblation with an Evac 70 wand, setting 9 with a pressure bag for copious saline irrigation (Arthrocare Corp, Sunnyvale, California), or argon electrocautery with the Conmed ABC system 7500 (Conmed Corporation, Utica, New York) with a 5-cm Tungsten ExplorAr needle point Argon Plasma Cutting Electrode (Surgical Technology Pty Ltd, Carlton Nth, Victoria, Australia), with coag setting 50 and gas flow 6 L/min.[8] After nasotracheal intubation (and any necessary palatal surgery), a dental chock was used between the molar teeth to hold open the mouth on the contralateral side. A 2-0 silk retraction suture was placed through the tongue tip. The original technique of a midline incision on the dorsal tongue mucosa, from the junction of the anterior and middle thirds of the tongue to 1 to 2 cm anterior to the circumvallate papillae, has been updated to an elliptical 2-cm-width incision (still commencing at the junction of the anterior and middle thirds of the tongue), encompassing the foramen cecum and extending posteriorly to the opposite tip of the epiglottis. This was to avoid distortion of dorsal shape from wound closure, which was found to be a much more important factor in maintaining normal tongue movement and taste than the risks of sacrificing several circumvallate papillae around the foramen cecum (**Figure 1**). The wound edges were retracted with stay sutures, and the mucosal incision was then deepened to a wedge midline glossectomy down to the genioglossus. Intraoperative ultrasound was used via the dorsum of the tongue to develop a plane 5 to 10 mm superficial to the lingual artery (and accompanying hypoglossal nerve) with a large straight hemostat. A portable ultrasound machine (Portable Logiqbook XP; GE Medical Systems, Milwaukee, Wisconsin) with a T-shaped probe (T739-RS intraoperative probe) was used in all cases, although a "hockey stick"–type probe may be used (**Figure 2**).

Once the plane superficial to neurovascular bundle was identified with the hemostat, the midline cavity was connected to it, by cutting onto the hemostat (**Figure 2**). A gently curved malleable retractor was inserted into the plane and pushed posteriorly. This malleable retractor tends to slide in the plane just superficial to the neurovascular bundle via blunt dissection when gentle pressure is applied posteroinferiorly toward a gloved finger in the vallecula (**Figure 3**). Excision of excessive lateral tongue bulk was then extended superficial and lateral to the neurovascular bundles in the middle and posterior thirds of the tongue (anteroposteriorly), leaving a cuff of 1 cm of muscle beneath dorsal and lateral tongue mucosa to minimize the risk of postoperative altered tongue function (**Figure 4**). At the completion of dissection of the first side of the tongue musculature, the dental chock was swapped sides to

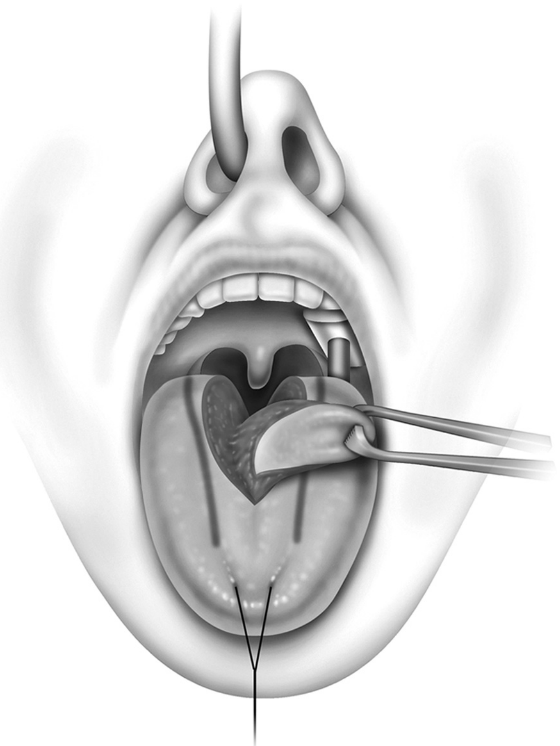

Figure 1. Tongue incision. A 2-0 silk suture is placed at the tongue tip. A long elliptical incision is made measuring 1 cm either side from the midline. The outline of the neurovascular bundle is shown at the edges of the incision. The posterior tip of the elliptical incision extends to the posterior third of tongue mucosa.

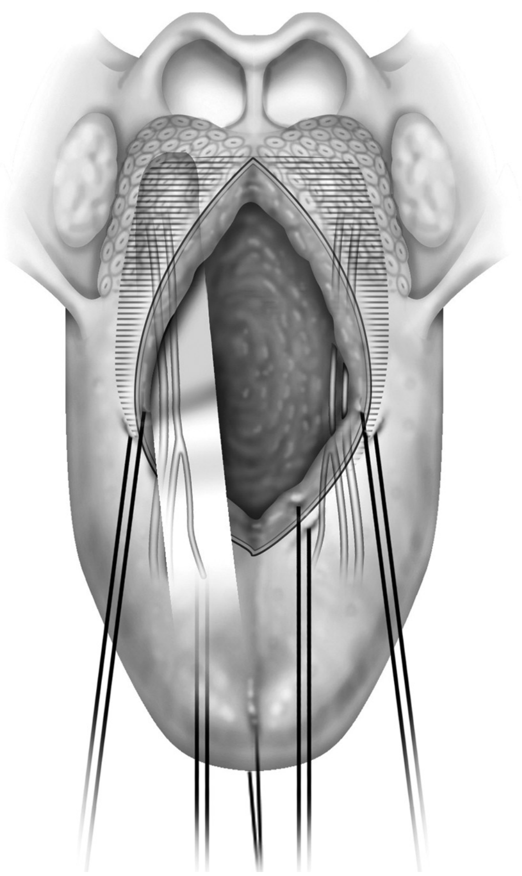

Figure 3. Extension of wound cavity posteriorly. Wound edges retracted with stay sutures and wound cavity deepened to the genioglossus. A blunt dissection with a gloved finger was applied posteriorinferiorly in the direction of the vallecula.

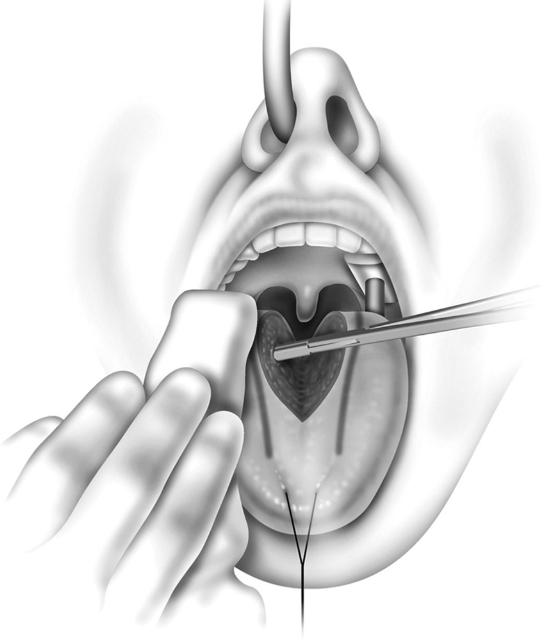

Figure 2. Identification of neurovascular bundle. A large straight hemostat is used to develop a plane 5 to 10 mm superficial to the neurovascular bundle that is identified with intraoperative ultrasound (probe on right side of tongue).

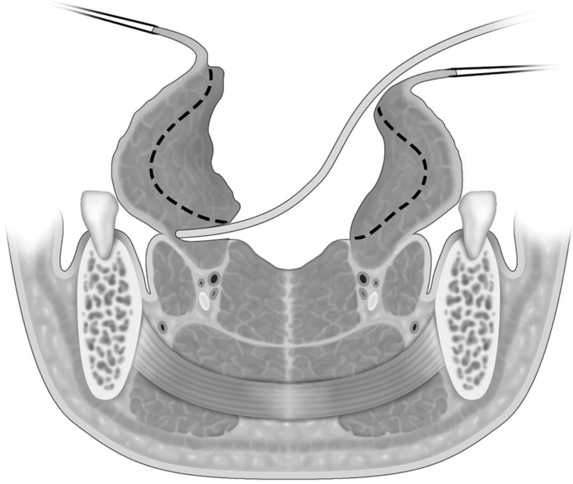

Figure 4. Lateral extension of wound cavity. A malleable retractor slides into the plane created with blunt dissection, superficial to the neurovascular bundle. Excision of the excessive tongue tissue removed superficial and lateral to the retractor leaves a cuff of 1 cm of muscle beneath the dorsal and lateral tongue mucosa.

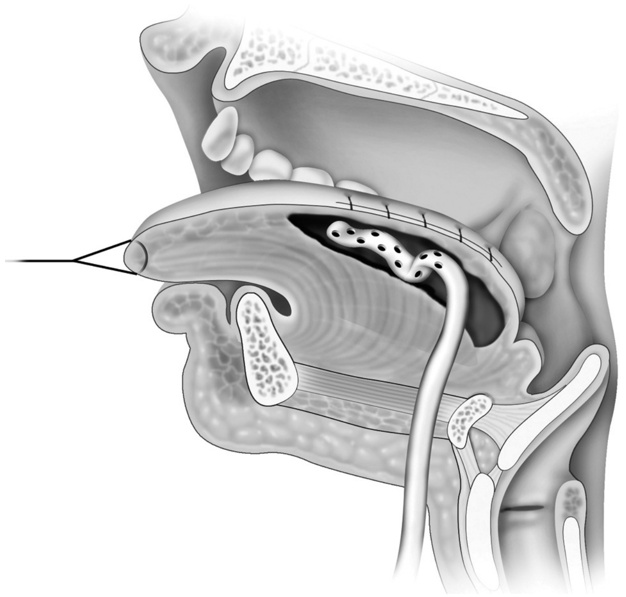

Figure 5. Closure of wound. Drain is positioned in the wound cavity via a suprahyoid approach and wound closed with tension-free interrupted sutures.

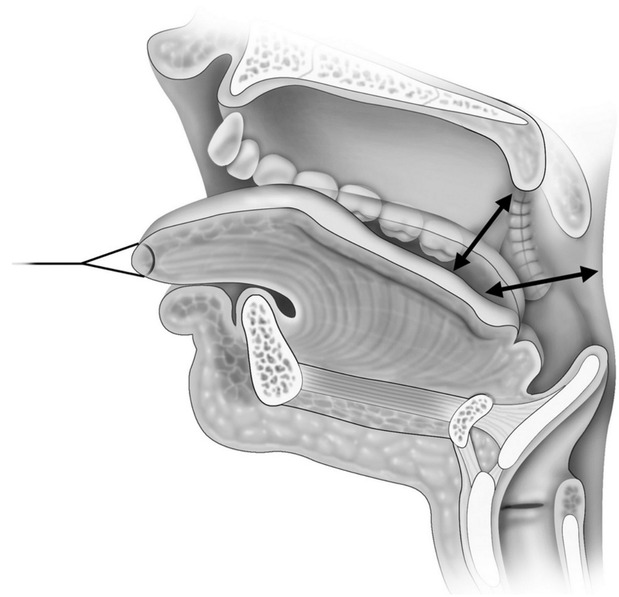

Figure 6. Changes in tongue position. Arrows show the increase in space from the dorsum of the tongue to the soft palate mucosa and posterior pharyngeal wall mucosa.

maintain access and minimize the risk of medial displacement of the neurovascular bundle during tongue muscle dissection. Posteriorly and medially between the neurovascular bundles and hyoglossus muscles, a further cuff of posterior genioglossus was excised if required. The posteroinferior limit of dissection is opposite the tip of the epiglottis, which is judged by palpation and direct visualization. It is *critically important to ligate any arterial branches* (ties or ligaclips), to avoid serious delayed bleeding up to 2 weeks postoperatively. Hemostasis was obtained at a mean arterial pressure of 110 mm Hg and Valsalva maneuver. A soft 15-gauge Jackson-Pratt suction drain was routinely used, via a suprahyoid stab incision and blunt tract dissection with a Robert's clamp to pull the drain through the tongue cavity and exit via the neck (**Figure 5**). Tension-free closure with 1 Biosyn interrupted sutures was performed, burying the knots. The drain was removed on the morning after surgery. **Figure 6** shows the postoperative increase in airway space and relationship of the tongue base in relation to the palatal and pharyngeal mucosal boundaries.

Postoperative management requires intensive care facilities. Patients were ventilated postoperatively to guard against (rare) delayed edema. In a routine case, no significant tongue swelling was seen, and the patient was extubated after 2 to 3 hours of observation and allowed a soft diet immediately. Broad-spectrum antibiotics were administered with steroids, which were continued for 5 days postoperatively. The patients were nursed on intensive care for the first 24 hours, with intra-arterial blood pressure monitoring to keep the mean arterial pressure <100 mm Hg with intravenous antihypertensive therapy and continuous oximetry. Discharge home was usually on the first or second postoperative day.

Polysomnography

All overnight polysomnographs were performed in a sleep laboratory attended by overnight sleep technicians. The recording was conducted and analyzed using computerized equipment (E-series) and software (Profusion PSG) from Compumedics Diagnostics Ltd (Abbotsford, Victoria, Australia) with manual scoring done by analysts accredited by the Board of Registered Polysomnographic Technologists. All scoring was performed according to standard protocol set by the American Academy of Sleep Medicine (AASM)[12-14] with alterations specified in the Australian Sleep Technologists Association (ASTA)/Australian Sleep Association (ASA) scoring guideline, in which the respiratory disturbance index (RDI) = apnea-hypopnea index (AHI) as the respiratory effort-related arousals (RERAs) are not scored.[15] Repeat assessment, including polysomnography, was undertaken 3.7 ± 0.4 months postoperatively. All studies were rescored to the current AASM 2007 recommended criteria.[16]

Questionnaires

Ethics approval was granted by the Southern Adelaide Clinical Human Research Ethics Committee. Postal questionnaires were sent to SML patients 2.6 ± 0.1 years postoperatively, consisting of the snoring severity score (SSS), Epworth Sleepiness Scale (ESS), and questions relating to changes in tongue function. Postoperative ESS scores were compared with preoperative ESS scores, sampled at the time of preoperative polysomnography. For SSS, both pre- and postoperative scores were collected via questionnaire. Comments regarding tongue function were collected via a further questionnaire. Defaulting patients were followed up with a single telephone contact.

Statistics

Patients were separated into mild and moderate to severe OSA groups using a preoperative AHI of <30 for mild and >30 for moderate to severe according to AASM 2007.[16] Dependent variables were generally skewed, and with a comparatively small sample size, nonparametric statistical tests were used. In particular, ranked analysis of covariance was used to compare mild vs moderate to severe OSA groups postsurgery after adjusting for presurgery results, whereas exact Wilcoxon signed rank tests were used to compare pre- and postsurgery results.

Results

Baseline Demographics

Baseline demographics are shown in **Table 1**.

Symptom Control

Outcomes summaries are shown in **Table 2**. The response rate for questionnaires was 70% (n = 19/27). Snoring remained well controlled 2.6 years after surgery, with the SSS falling from 7.1 ± 0.4 to 2.3 ± 0.6 ($P < .05$). The ESS fell from 8.3 ± 1.1 to 5.8 ± 1.0 ($P < .05$).

Postsurgical Polysomnography

Evaluation of PSG at a minimum of 3 months postoperatively showed significant improvements in a number of sleep study parameters; importantly, AHI fell from 44.0 ± 4.3 to 12.5 ± 2.3 ($P < .05$). Also, in those patients with moderate to severe OSA (preoperative AHI >30, n = 19), the AHI fell from 53.3 ± 4.7 to 11.6 ± 2.6 ($P < .05$). For patients with moderate to severe OSA, "success," defined as achieving a postoperative AHI <15, occurred in 79% (15/19), and each achieved a reduction in preoperative AHI >50%. For patients with mild OSA, "success" occurred in 63% (5/8), and each achieved a reduction in preoperative AHI >50%.

The 4% oxygen desaturation index (4% ODI) fell from 26.1 ± 4.2 to 6.1 ± 1.0 ($P < .05$). In cases with a preoperative 4% ODI >20 (n = 12), all achieved a postoperative 4% ODI <20. Significant improvements were also observed with lowest oxygen saturation (Lsat $P < .05$), arousal index ($P < .05$), % sleep time ($P < .05$), and % rapid eye movement (%REM) sleep ($P < .05$), with the exception of % sleep efficiency ($P > .05$) (**Table 2**). No significant change in body mass index (BMI) was observed during the 3-month follow-up period ($P > .05$).

Surgical Complications

The most serious complication was delayed bleeding and tongue hematoma, occurring in 1 of 27 (3.7%) patients. Tongue wound dehiscence was observed in 4 of 27 (14.8%). No postoperative infections were recorded when monofilament suture was used for wound closure, which occurred halfway through the series. Pain appeared to mirror dehiscence/infection rates, with pain typically controllable with oral analgesia from the first postoperative day in those with intact mucosal closure.

Questionnaires were returned by 19 of 27 patients; 3 declined to participate, and 5 could not be contacted. Short-term alteration in tongue function was frequently seen initially, with patients reporting some change in speech, swallowing, and taste (**Table 3**). Long-term (6 months) altered tongue function was reported as speech, 47%; swallow, 33%; and taste, 33%. However, those with residual deficits all rated their impairment as minor with a mean visual analog scale (VAS) score less than 2 out of 10 (**Table 3**). No hypoglossal nerve weakness was noted in any cases. No long-term cases of globus pharyngeus were recorded.

Discussion

Although there are a number of suggested ways of reporting success or failure of interventions for OSA, consensus has now emerged that the 2 aims of any OSA therapy are first to control symptoms and second to achieve mild or absent OSA objectively (where no consistent evidence of adverse health effects has been demonstrated).[1] In this series, long-term symptom control (SSS and ESS) was good. The AHI threshold that is used to separate mild from moderate or greater disease varies in the scientific literature. We used the current AASM 2007 recommended criteria. In this study, a significant improvement was noted in the AHI levels in the patients with moderate to severe OSA.

Previous investigators have shown a strong correlation between increasing BMI and increasing tongue volume on magnetic resonance imaging (MRI) 3-dimensional scanning.[17-19] A consistent association between poorer outcomes in tongue tensioning procedures and increasing BMI has been demonstrated in a recent evidence-based medicine review of tongue OSA surgery,[4] and we believe this is likely due to the association between macroglossia and increased BMI. A randomized controlled trial of UPPP and tongue suspension suture vs UPPP and radiofrequency tongue ablation has shown a marked drop in the efficacy of the tongue suspension suture at a cut point of BMI 29.4 (success = 90% below BMI 29.4 vs 10% above).[18] Similarly, other groups have demonstrated a significant reduction in the short- and long-term success rate with geniotubercle advancement above a BMI of 30 to 32.3[19,20] and mortised genioplasty above a BMI of 30.[21]

In 2007, our first-choice procedure for retrolingual obstruction in mild to moderate OSA was coblation tongue channeling (CTC), with concurrent treatment of palatal-level collapse. Submucosal lingualplasty was the procedure of choice in patients with moderate to severe OSA with macroglossia and for salvage of failed CTC cases. The paradigm under which reconstructive procedures were chosen assumed that the larger the tongue, the more volume could be removed and the more effective SML was likely to be on the airway. The converse was true for tensioning procedures, which appear to have less effect with elevation of BMI and AHI.[4]

Table 2. Summary of Pre- and Postoperative Patient Characteristics and Polysomnography Results

	Pre-SML		Post-SML	
	Median	Mean ± SEM	Median	Mean ± SEM
ESS				
All patients	8.5	8.3 ±1.1	5.0	5.8 ± 1.0*
Moderate-severe OSA	7.0	7.1 ± 1.2	4.0	4.7 ± 1.0*
Mild OSA	11.0	11.0 ± 2.3	10.0	8.0 ± 2.1
SSS				
All patients	8.0	7.1 ± 0.4	2.0	2.3 ± 0.6*
Moderate-severe OSA	7.5	7.0 ± 0.5	1.0	2.0 ± 0.6*
Mild OSA	8.0	7.4 ± 0.6	3.0	3.4 ± 1.6
AHI				
All patients	36.7	44.0 ± 4.3	7.7	12.5 ± 2.3*
Moderate-severe OSA	45.1	53.3 ± 4.7	8.3	11.6 ± 2.6*
Mild OSA	22.0	21.8 ± 1.3	6.4	14.7 ± 5.2
ODI 4%				
All patients	18.9	26.1 ± 4.2	4.8	6.1 ± 1.0*
Moderate-severe OSA	29.4	33.1 ± 4.9	5.6	6.3 ± 1.1*
Mild OSA	7.5	9.0 ± 1.8	3.5	5.5 ± 2.3
Lsat				
All patients	84.0	84 ± 1	90.0	88 ± 1*
Moderate-severe OSA	84.0	82 ± 1	90.0	88 ± 2*
Mild OSA	90.0	90 ± 1	87.0	88 ± 1
% Sleep time <90%				
All patients	2.0	7.4 ± 3.3	0.0	3.7 ± 2.3*
Moderate-severe OSA	3.0	10.2 ± 4.4	0.0	5.0 ± 3.1*
Mild OSA	0.0	0.2 ± 0.2	0.0	0.2 ± 0.2
Arousal index				
All patients	42.0	39.6 ± 4.1	19.0	23.0 ± 2.5*
Moderate-severe OSA	51.0	46.3 ± 4.6	18.0	22.2 ± 3.0*
Mild OSA	25.5	25.0 ± 4.6	23.0	24.7 ± 4.9
Sleep efficiency, %				
All patients	71.0	72.6 ± 3.0	77.5	76.4 ± 2.9
Moderate-severe OSA	71.0	70.9 ± 3.8	75.5	73.0 ± 3.6
Mild OSA	76.0	76.3 ± 4.8	84.5	84.3 ± 3.1
REM %				
All patients	16.0	15.2 ± 1.7	20.0	19.1 ± 1.7*
Moderate-severe OSA	13.5	12.7 ± 2.0	19.0	17.9 ± 1.8*
Mild OSA	19.5	20.3 ± 1.9	23.0	21.5 ± 3.5
BMI				
All patients	31.0	30 ± 1	29.0	30 ± 1
Moderate-severe OSA	32.0	32 ± 1	30.0	30 ± 1*
Mild OSA	26.0	27 ± 2	27.0	28 ± 3

Abbreviations: AHI, apnea-hypopnea index; BMI, body mass index; ESS, Epworth Sleepiness Scale; Lsat, lowest oxygen saturation; ODI, oxygen desaturation index; OSA, obstructive sleep apnea; REM, rapid eye movement; SEM, standard error of the mean; SML, submucosal lingualplasty; SSS, snoring severity score.
*$P < .05$, exact Wilcoxon signed rank tests.

The subjective and objective response rates in this series suggest that SML is a clinically effective intervention in this group of patients, with PSG outcomes similar to previously published mucosal sacrificing glossectomy series and maxillomandibular advancement, but with a high rate of patient acceptance.[5-7]

Although there is no control group in this study, anatomical staging would suggest poor outcomes in this series with UPPP alone (predicted 5% success with combined palatal and tongue collapse) and the 2:1 ratio of Friedman stage 3:2 on initial examination (predicted 18.6% success).[2,9] Interpretation of outcomes in this study should also be in the context of all patients having combined UPPP and PA with SML, rather than UPPP and SML alone. Level 3 evidence shows improved outcomes for combined UPPP/PA vs UPPP alone in Friedman stage 3

Table 3. Summary of Postoperative Complications as Reported by Patients in Long-Term Follow-up Questionnaire

Complications			No. Patients	Median	Mean ± SD	Range
Pain	VAS	At worst	19	8	7.1 ± 0.5	2-10
Speech	Experienced change	Yes	17			
		No	1			
	Duration, d	Resolved	9	20	41 ± 12	7-100
		Ongoing	8			
	VAS	At worst	14	6	6.1 ± 0.6	2-10
		2.6 y postoperatively	14	2	2.0 ± 0.5	0-7
Swallowing	Experienced change	Yes	15			
		No	3			
	Duration, d	Resolved	10	20	30 ± 9	10-100
		Ongoing	5			
	VAS	At worst	11	7	6.6 ± 0.7	2-10
		2.6 y postoperatively	11	1	1.1 ± 0.4	0-5
Taste	Experienced change	Yes	9			
		No	9			
	Duration, d	Resolved	6	22	39 ± 14	14-100
		Ongoing	3			
	VAS	At worst	9	6	6.2 ± 0.5	5-10
		2.6 y postoperatively	9	0	1.7 ± 0.9	0-7
Lump in throat	Experienced change	Yes	7			
		No	11			
	Duration, d	Resolved	7	30	37 ± 11	14-90
		Ongoing	0			
	VAS	At worst	4	6	6.8 ± 1.1	5-10
		2.6 y postoperatively	4	0	0.5 ± 0.5	0-2
Other surgery-related problem	Experienced change	Yes	7			
		No	9			
		Not answered	2			
	Description	Dry throat/mouth; lumpy swollen tongue; phlegm buildup; postoperative infection; sore tongue; still snoring; wasting of one side of tongue				
	Duration, d	Resolved	2	37	37 ± 23	14-60
		Ongoing	5			
	VAS	At worst	6	7.3	6.7 ± 0.7	3.5-8.0
		2.6 y postoperatively	6	1.5	2.1 ± 1.0	0-6.5

Abbreviation: VAS, visual analog scale.

patients when controlled for multiple variables, and it is likely that outcomes would have been less successful if only UPPP and SML were performed.[22] Although we chose to perform concurrent PA and UPPP in patients at high risk of failure at the palate after UPPP alone, staging PA as a salvage treatment for ongoing retropalatal collapse after UPPP and SML is a reasonable approach and would likely achieve similar outcomes to this series.

The most serious short-term complication was tongue hematoma, seen in 1 patient in this series, due to lateral tongue dissection exposing small vessels. This manifests as a rapid increase in tongue size, with increasing pain and oral bleeding, progressing over 1 to 2 hours. To minimize this complication, a drain was inserted during tongue wound closure. Awake fiber-optic intubation was performed, the hematoma was evacuated, and hemostasis was obtained. This is a life-threatening complication that needs careful planning to successfully salvage by any center wishing to perform this surgery. All patients should be instructed to stay within an hour's drive of the hospital for 2 weeks postoperatively and have the surgeon's contact details, so rapid return to the operating room can be arranged.

In this series, there is a small but measurable long-term (greater than 6 months) impact on tongue function in some patients. We noted that infection and wound dehiscence resulted in healing by secondary intention, with a greater tendency for midline tongue scar deposition and/or an abnormally deep midline groove, which may then impair tongue function. In retrospect, we also concluded that several cases may have had overzealous muscle resection laterally, hence the current recommendation of leaving a 1-cm muscle cuff beneath the dorsal and lateral mucosa. With the fall in infection rates by changing from braided to monofilament sutures, as well as avoidance of overresection of tongue muscle, the issue of tongue function impairment should be minimal.

The globus pharyngeus rate after UPPP has been reported as 27% in a recent systematic review.[23] The low rate of globus pharyngeus in this study suggests an important secondary effect of widening the oropalatal airway by tongue reduction. This creates space into which advancement of the free edge of the soft palate can occur during UPPP $\pm$ PA to minimize globus pharyngeus risk.

The strengths of this study are a series of consecutive patients by a single surgeon with prospective data collection having a standardized procedure for defined OSA pathophysiology. Subjective and objective outcomes (the ESS, SSS, AHI, ODI 4%, Lsat, % sleep time <90%, arousal index, and REM% all showing statistically significant improvement; **Table 2**) are presented to demonstrate that SML is an effective operation in a subgroup of OSA patients with macroglossia, for which there are currently few reliable or acceptable surgical options in contemporary clinical practice. Weaknesses of this study are the generalizability of the results, as the surgeon (S.R.) who developed this operation performed all surgeries on all patients in this series. We would encourage surgeons with an interest in upper airway surgery for OSA to consider SML for patients with macroglossia with a view to publish their results, as we believe it is likely that they will achieve similar outcomes to this article. We acknowledge that a weakness in the results is that a full data set for the ESS and SSS was not available. The SSS pre- and postoperative scores were both generated at the time of long-term follow-up; therefore, the change in values was a retrospective analysis, introducing possible bias. However, even if the baseline SSS values and change in SSS are ignored, the current long-term postoperative SSS values are very low, indicating good long-term control of snoring. We acknowledge that objective sleep study data were shorter term than the long-term quality-of-life (QOL) outcomes. We also acknowledge that other important potential OSA outcome measurements would have been ideal but were beyond the scope of this study (eg, sleep-specific QOL, reaction time, car crash risk assessment, mortality risk, etc).

Conclusion

Submucosal lingualplasty (with appropriate palatal surgery) is a promising treatment option in adult patients with obstructive sleep apnea with macroglossia. Most reported postoperative alterations in tongue function resolved within 1 to 2 months, and any patients with long-term detectable change rated the disturbance as minor.

Dedication

This article is dedicated to the late Dr Sam Robinson.

Author Contributions

Indunil Gunawardena, analysis of data, drafting article, final approval; **Sam Robinson**, design, acquisition of data, analysis of data, final approval; **Stuart MacKay**, analysis of data, drafting of article, final approval; **Charmaine M. Woods**, analysis of data, revising article, final approval; **June Choo**, acquisition of data, revising article, final approval; **Adrian Esterman**, analysis of data, revising of article, final approval; **A. Simon Carney**, analysis of data, revising article, final approval.

Disclosures

Competing interests: A. S. Carney, member of the international medical advisory board of Arthrocare.

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