The New Generation of Palate Surgery for Obstructive Sleep Apnea

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2.1 Introduction

Obstructive sleep apnea (OSA) is categorized under the sleep disordered breathing continuum ranging from simple snoring to OSA. OSA due to upper airway collapse arising from pharyngeal and tongue muscle relaxation during sleep results in hypoxemia with increased sympathetic overdrive, increased blood pressure, and hypercapnia. The stoppages in breathing would result in arousals from sleep and sleep disruptions causing sleep fragmentation leading to excessive daytime sleepiness, tiredness, lethargy, morning headaches, poor concentration, fatigue, poor memory, and irritability.

Most sleep specialists have shown a strong correlation between OSA and hypertension, atherosclerosis, and cerebrovascular accidents (strokes) [1]. Studies have also shown a higher mortality rate among patients with cardiovascular disease who also have OSA [1]. Therefore, it would be reasonable to say that early and effective treatment of OSA is of great essence.

Treatment of OSA can range from nasal continuous positive airway pressure (CPAP) as the "gold" standard, to oral appliances, to upper airway surgery. Upper

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airway surgery has evolved and improved significantly over the past 10–20 years [2–12]; however, the concept of surgical success has not changed much during this period (50% reduction and/or AHI apnea-hypopnea index (AHI) <20) [13].

In the 1960s, Quesada and Perello [14] introduced the more ablative technique of treating snoring by the removal of the uvula and soft palatal soft tissue. Forty years on, new palatal techniques have been introduced; in the early 2000s, Michel Cahali [15] introduced the lateral pharyngoplasty which had promising results, while Pang and Woodson introduced the expansion sphincter pharyngoplasty [16], which showed far better outcomes for patients with lateral pharyngeal wall collapse.

The basic fundamentals of the new generation of palate surgeries are:

(a) to address the exact anatomical site of collapse,
(b) preserving the mucosa and soft tissues,
(c) while respecting muscle and anatomical function of each structure.

Coupled with these newer palatoplasty techniques, one must not forget the introduction of more comprehensive methods for airway evaluation. Drug induced sleep endoscopy (DISE) has changed the reality of what the airway is when asleep versus when awake. Studies have shown that the treatment plans of patients with and without DISE performed are markedly changed in over 60–70% of patients [17–20] (whether they had DISE performed before their surgery).

The authors discuss the systematic review of the medical literature and meta-analysis of papers on upper airway palate surgery for OSA between the years January 2001 and February 2018 and review the success rates of palate surgery over the past 17 years.

2.2 Methodology

A comprehensive systematic literature review using searches of MEDLINE, Google Scholar, Cochrane Library, PubMed, and Evidence Based Medicine Reviews to identify publications relevant to OSA treatment and upper airway palate surgery with its variants. All relevant studies published between January 2001 and December 2017 were included.

The authors looked at surgical outcomes and results, with the inclusion criteria being:

1. ***Patients:*** adults, more than 18 years of age, with AHI > 5.
2. ***Comparison:*** quantitative data pre- and post-palate surgery.
3. ***Outcomes:*** including either success rates of treatment, pre-operative and post-operative AHI, Epworth sleepiness scale (ESS), quality of life (QOL), and/or snoring visual analog scale (VAS).
4. ***Study design:*** published, peer-reviewed studies with at least a 3 month follow-up period post-surgery.

5. ***Intervention***: palatal surgery involving either the soft and/or hard palate, lateral pharyngeal wall, palatopharyngeus, with or without tonsil surgery and/or uvular procedure. The authors excluded (a) procedures performed in addition to palate surgery (i.e. tongue surgery, skeletal surgery), (b) LAUP, (c) studies with qualitative outcomes only, (d) patients who had previous upper airway surgery, and (e) patients who have central sleep apnea.

The following combined search terms were used on PubMed and MedLine (using both British and American spellings): "upper airway surgery and sleep apnea/obstructive sleep apnea," "palate surgery and sleep apnea/obstructive sleep apnea," "airway modifications and sleep apnea/obstructive sleep apnea," "pharyngoplasty and sleep apnea/obstructive sleep apnea," "palatoplasty and sleep apnea/obstructive sleep apnea," "tonsil surgery and sleep apnea/obstructive sleep apnea," "systematic review and sleep apnea/obstructive sleep apnea," and "meta-analysis and sleep apnea/obstructive sleep apnea."

A total final number of 59 articles were identified and included. The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement and checklist were followed as much as possible during this review.

The authors analyzed the pooled results (pre-operative and post-operative) of all palate procedures performed on the entire group of OSA patients. The authors also looked at the results (pre-operative and post-operative) of the three main categories of palate procedures (namely lateral/expansion palatal procedures, anterior palatal procedures, and the classic uvulopalatopharygoplasty).

2.3 Statistical Method

Meta-analysis was conducted using the Cochrane Review Manager (version 5.3), (The Nordic Cochrane Centre, The Cochrane Collaboration). Random effect models are used to generate pooled estimates. Data was analyzed using generic inverse radiance method and $p < 0.05$ is regarded as statistically significant. Combined summary statistics of the standardized (STD) paired difference in mean for the individual studies are shown. Combined STD paired differences in means were calculated and a 2-sided p-value <0.05 was considered to indicate statistical significance. An χ^2-based test of homogeneity was performed and the inconsistency index (I^2) statistic was determined. If I^2 was >50% or >75%, the studies were considered to be heterogeneous or highly heterogeneous, respectively. If I^2 was below 25%, the studies were considered to be homogeneous. If the I^2 statistic (>50%) indicated that heterogeneity existed between studies, a random effects model was calculated. For the second part, due to the high heterogeneity in each subgroup (I^2 = 91.4% $p < 0.001$, I^2 = 89.8% $p < 0.001$, and I^2 = 95.0% $p < 0.001$, respectively), a random effects analysis was performed using the DerSimonian and Laird method. In order to check the differences in the reduction on AHI between each surgical technic, Z-scores have been computed. A p-value <0.05 has been considered statistically significant. The entire meta-analysis was carried out using "Stata IC 12.1."

2.4 Results

The PubMed/Medline database search revealed 2103 papers, 945 papers were not relevant, a further 802 did not meet the inclusion criteria; 243 papers were on multi-level upper airway surgery, 99 papers were subsequently excluded for they did not document pre- and post-surgery AHI, finally, 14 papers were not included as they lacked documentation of follow-up duration, leaving 59 papers [15–73] that met the inclusion criteria.

There were a total of 59 scientific papers included for analysis. All these papers met the inclusion criteria and reported their results in a clear and concise way. A total of 2694 patients underwent a varied number of palatal surgery types that included the traditional uvulopalatopharyngoplasty (UPPP), Han modified UPPP, uvulo-palatal flap (UPF), extended UPF (EUPF), modified extended UPF (MEUP), Z-palatoplasty (ZPPP), lateral pharyngoplasty (LP), relocation pharyngoplasty (RP), expansion sphincter pharyngoplasty (ESP), anterior palatoplasty (AP), functional expansion sphincter pharyngoplasty (FESP), limited palatal muscle resection (LPMR), barbed anterior palatoplasty (BAP), partial palate resection (PPR), soft palatal webbing flap palatopharyngoplasty (SPWF), barbed Roman blinds technique (BRBT), barbed repositioning pharyngoplasty (BRP), anterolateral advancement pharyngoplasty (AAP), and the barbed expansion sphincter pharyngoplasty (BESP) (Table 2.1).

The authors showed that many sleep specialists/surgeons have moved away from the traditional UPPP and/or its modified variants. Ever since the introduction of the Cahali [15] LP in 2003 and the Pang et al. [16] ESP in 2007, most surgeons have adopted and utilized the newer innovative techniques to address the lateral pharyngeal wall collapse and anterior–posterior soft palatal narrowing.

Over the past 18 years (January 2001 to February 2018), the authors described that (in these 59 papers) the uvulopalatopharyngoplasty technique only accounted for 16.7% of all the 2715 pooled patient procedures performed.

Interestingly, from January 2001 to December 2010, the percentage of UPPP procedures were 25.6% (264 out of 1034), and from January 2011 to February 2018, the percentage of UPPP procedures were only 12.6% (213 out of 1681).

From the 59 papers analyzed, there were 2715 patients who had upper airway surgery and met the criteria. The average follow-up was 8.18 months (range 6 to 54 months). The mean decrease in AHI (pre- to post-procedure) was from 35.66 to 13.91 ($p < 0.001$). The mean decrease in ESS (pre- to post-procedure) was from 11.65 to 5.08 ($p < 0.001$). The mean AHI change was 19.9 (SD 8.32, range of 4.9 to 36.9) ($p < 0.001$). The mean ESS change was 5.8 (SD 2.2, range of 2 to 10) ($p < 0.001$). The overall pooled success rate was 67.5% (the range of success rates was from 25% to 94.1%).

After having divided the procedures into the three main categories, the meta-analysis of the respective palate procedure showed that the surgical technique that achieved the better reduction on AHI was the anterior palatoplasty, with a mean reduction of 24.7 (range 20.79–28.6) ($p = 0.015$), while the mean reduction

Table 2.1 Table with the 59 articles; traditional uvulopalatopharyngoplasty (UPPP), Han modified UPPP, uvulo-palatal flap (UPF), extended UPF (EUPF), modified extended UPF (MEUP), Z-palatoplasty (ZPPP), lateral pharyngoplasty (LP), relocation pharyngoplasty (RP), expansion sphincter pharygoplasty (ESP), anterior palatoplasty (AP), functional expansion sphincter pharyngoplasty (FESP), limited palatal muscle resection (LPMR), barbed anterior palatoplasty (BAP), partial palate resection (PPR), soft palatal webbing flap palatopharyngoplasty (SPWF), barbed Roman blinds technique (BRBT), barbed repositioning pharyngoplasty (BRP), anterolateral advancement pharyngoplasty (AAP), and the barbed expansion sphincter pharyngoplasty (BESP), modified radiofrequency tissue ablation (MRFTA)

	Author	Ref.	Year	*N*	Technique	Type	F-UP (months)	AHI pre	AHI post	Success rate (%)	ESS pre	ESS post
1	Cahali	15	2003	10	LP	Lat	8.2	41.2	9.5	60	13	5
2	Li et al.	17	2003	33	EUPF	AP	6	41.6	12.5	81.8	n.a.	n.a.
3	Cahali et al.[a]	18	2004	15	LP	Lat	7.9	41.6	15.5	53.3	14	4
				12	UPPP	Clas	8.2	34.6	30.0	41.7	14	5
4	Friedman et al.	19	2004	25	Z-PPP	Lat	6	41.8	20.9	68	12.5	8.4
				25	UPPP	Clas	6	33.4	25.2	28	14.2	8.7
5	Li et al.	20	2004	105	EUPF	AP	12	43.8	15	80	n.a.	n.a.
6	Li et al.	21	2004	55	EUPF	AP	6	43.6	21.1	82	11.8	7.5
7	Li et al.	22	2004	84	EUPF	AP	6	46.5	14.6	n.a.	11	7.2
8	Han et al.	23	2005	68	Han-UPPP	AP	6	32.1	12.7	69.1	10.1	4.5
9	Li et al.	24	2005	50	EUPF	AP	6	44.5	13.4	84	n.a.	n.a.
10	Hofmann et al.	25	2006	47	UPPP	Clas	4	8.0	5.0	n.a.	n.a.	n.a.
11	Li et al.	26	2006	110	EUPF	AP	6	44.4	15	78.2	n.a.	n.a.
12	Lin et al.	27	2006	55	EUPF	AP	6	43.6	12.1	82	11.8	7.3
13	Pang and Woodson[a]	16	2007	23	ESP	Lat	6	44.2	12	82.6	n.a.	n.a.
				22	UPPP	Clas	6	38.1	19.6	68.1	n.a.	n.a.
14	Huang and	28	2008	50	MEUP	AP	6	37.9	6.1	80	9.8	5.2
15	Li and Lee	29	2009	10	RP	Lat	6	43.4	15.7	50	9.6	6.3
16	Lundkvist et al.	30	2009	158	UPPP	Clas	12	27.2	10.8	64	12.0	6.0
17	Pang et al.	31	2009	77	AP	AP	33	25.3	11.0	71.8	16.2	7.9

(continued)

Table 2.1 (continued)

	Author	Ref.	Year	*N*	Technique	Type	F-UP (months)	AHI pre	AHI post	Success rate (%)	ESS pre	ESS post
18	Lee et al.	32	2011	30	RP	Lat	6	46.2	17.9	n.a.	10.8	6.5
19	Neruntarat	33	2011	83	UPF	AP	54	45.6	19.4	51.8	16.4	7.7
20	Mantovani et al.	34	2012	4	VUPL	Lat	6	15.5	n.a	n.a.	11.5	5.5
21	Choi et al.	35	2013	20	UPPP	Clas	3	37.2	20.1	n.a.	11.6	7.3
22	Li et al.	36	2013	47	RP	Lat	6	59.5	22.6	49	12.2	7.5
23	Browaldh et al.[a]	37	2013	32	UPPP	Clas	6	53.3	21.1	59	12.53	6.8
24	Kim et al.	38	2013	92	UFP+LP	Lat	6	39.1	7.9	78	11.1	6.6
25	Liu et al.	39	2013	51	Han-UPPP/ZP	Lat	6	65.6	29.5	45.1	12.8	5.5
				31	Han-UPPP		6	n.a	n.a	35.5	n.a.	n.a.
				20	Z-PPP		6	n.a	n.a	60	n.a.	n.a.
26	Marzetti et al.[a]	40	2013	19	UPF	AP	6	23	9.6	84	8.1	5.2
				15	AP	AP	6	22	8.6	86	8.5	4.9
27	Sorrenti and Piccin	41	2013	85	FESP	Lat	6	33.3	11.7	89.2	n.a.	n.a.
28	Yousuf et al.	42	2013	22	UPPP	Clas		43.1	13.2	95.2	n.a.	n.a.
29	Cho et al.	43	2014	23	LPMR	AP	6	32	5.6	n.a.	11.8	6
30	de Paula Soares et al.	44	2014	18	LP	Lat	6	33.5	20.9	50	n.a.	n.a.
31	Salamanca et al.	45	2014	24	BAP	Lat	6	8.9	3.8	n.a.	n.a.	n.a.
32	Ugur et al.	46	2014	42	AP	AP	24	13.2	7.1	51.7	11.5	8.3
33	Chen et al.	47	2015	32	RP	Lat	6	42.8	12.0	59.4	12.0	8.0
34	Chi et al.	48	2015	25	LP	Lat	6	34.1	17.3	n.a.	10.5	7.7

35	Carrasco-Llatas et al.	49	2015	22	PPR	Clas	7	47.2	18.4	72.7	n.a.	n.a.
				7	UPPP	Clas	7	47.3	12.0	71.4	n.a.	n.a.
				4	ZP	Lat	7	22.5	13.9	25	n.a.	n.a.
				10	LP	Lat	7	48.0	15.2	70	n.a.	n.a.
				10	ESP	Lat	7	27.7	6.5	90	n.a.	n.a.
36	Dizdar et al.	50	2015	14	LP	Lat	20	23.9	11.3	100	15.3	6.8
				9	UPPP	Clas	20	25.1	8.0	100	15.1	5.1
37	Elbassiouny	51	2015	28	SPWF	Lat	6	46	11	n.a.	n.a.	n.a.
38	Li et al.	52	2015	32	RP	Lat	6	18.3	5.9	n.a.	12.0	7.0
39	Li et al.	53	2015	60	RP	Lat	6	44.2	20.1	50	11.4	7.8
40	Mantovani et al.	54	2015	32	BRBT	Lat	12	36.9	13.7	84.4	15.3	5.7
41	Vicini et al.	55	2015	10	BRP	Lat	6	43.6	13.6	90	11.6	4.3
42	Emara et al.	56	2016	41	AAP	AP	6	42.1	16.3	87	16.3	8.1
43	Pang et al.	57	2016	73	AP+FESP	Lat	6	26.3	12.6	86.3	11.5	2.9
44	Sommer et al.[a]	58	2016	23	UPPP+TA	Clas	6	33.7	15.4	70	10.6	6.2
45	Wu et al.[a]	59	2016	24	UPPP	Clas	6	39.7	18.4	62.5	11.5	6.17
				24	UPPP-double suture	Clas	6	39.13	18.96	70.8	11.25	5.96
46	Adzreil et al.	60	2017	31	AP+TA	AP	12	35.0	18.5	32	13.3	7.1
47	Amali et al.[a]	61	2017	19	UPPP	Clas	6	20.15	10.03	77	12.07	6.87
				20	MRFTA	Clas	6	19.42	13.39	30	13.4	7.67
48	Askar et al.	62	2017	22	ESP-doublesuture	Lat	6	29.7	7.9	n.a.	12.3	4.6
49	Atan et al.	63	2017	14	AP+FESP	Lat	6	17.8	12.9	n.a.	n.a.	n.a.
50	Binar et al.	64	2017	23	FESP	Lat	6	32.36	11.79	69.6	11.82	5.21

(continued)

Table 2.1 (continued)

	Author	Ref.	Year	*N*	Technique	Type	F-UP (months)	AHI pre	AHI post	Success rate (%)	ESS pre	ESS post
51	Cammaroto et al.	65	2017	10	UPPP	Clas	6	37.8	22.9	50	12.3	8.5
				10	ESP	Lat	6	35.6	9.6	90	13	4.9
				10	BRP	Lat	6	34.04	13.5	90	10.4	3.9
52	Despeghel et al.	66	2017	35	FESP	Lat	6	41.3	17.4	53	n.a.	n.a.
53	El-Ahl et al.	67	2017	24	ESP-suspension	Lat	6	28.6	8.9	n.a.	11.7	5.1
54	Mantovani et al.	68	2017	19	ALIANZA	Lat	6	22.3	7	52	11.3	3.9
55	Montevecchi et al.	69	2017	111	BRP	Lat	6	33.4	13.5	73	10.2	6.1
56	Pianta et al.	70	2017	17	BESP	Lat	12	31.1	7.8	94.1	6	4
57	Rashwan et al.	71	2017	25	UPPP+TA	Clas	6	18.96	12.88	n.a.	8.8	7.34
				25	ESP	Lat	6	19.14	9.01	n.a.	8.96	4.12
				25	BRP	Lat	6	25.58	9.82	n.a.	9.28	3.76
58	Suslu et al.	72	2017	28	ESP	Lat	6	31	19.6	57	n.a.	n.a.
59	Plaza et al.	73	2018	75	ESP	Lat	12	22.1	8.6	69.3	11.5	4.7
	TOTAL			2715								
				2715			8.18	35.66	13.91	67.50	11.65	5.08

[a]Randomized controlled trials

of AHI for the lateral/expansion pharyngoplasty procedures was 19.8 (range 16.90–22.64) ($p = 0.046$), and the mean reduction of AHI for the classical uvulo-palatopharyngoplasty was 17.2 (range 12.68–21.83) ($p = 0.360$).

2.5 Discussion

Since the late 1960s, the understanding and management of OSA have evolved and deepened. Sleep specialists widely accept that upper airway surgery can have good success rates for selected OSA patients who have favorable anatomical surgical structure. Most agree that the key to surgical success is patient selection, hence, clearer visualization of the airway during drug induced sleep endoscopy (DISE) [74–81] has enhanced the surgeon's ability to select the appropriate procedure for the appropriate patient.

Since the beginning of the early 2000s, DISE has enabled sleep surgeons to visually locate the exact anatomical site that collapses during the patient's sleep, hence, addressing that particular anatomical site. In addition, since 2003, the introduction of the LP [15, 18] and the ESP [16, 57, 82] in 2007, these 2 newer techniques have revolutionized the concept of sleep apnea surgery from ablative surgery to one that involves reconstruction while preserving the function of the uvula and sparing more mucosa.

Over the past 40 years, there has been an improvement in the success rates of palate surgery from 40.7% [8, 9], to 55% [83] to this current meta-analysis at 69.6%, in comparison to a systemic review by Rotenberg and Pang et al. [84], who reviewed 82 papers over a 20-year (1994–2015) CPAP treatment period, and demonstrated that the non-adherence rate of CPAP therapy remained high at 34% (plateau) throughout these 20 years. Despite improvements in the CPAP technology, dynamic breath-to-breath pressure titration, and including the use of Bi-level therapy, CPAP compliance has been at a dismal low level.

The authors demonstrate a clear shift of the sleep surgeons' preference towards more innovative anatomically targeted surgical procedures, instead of the old traditional non-selective UPPP. It demonstrates a change in philosophy in the thought process of sleep surgeons and that sleep surgeons are aware that sleep apnea surgery is reconstructive and not ablative surgery. The steady decrease of the UPPP technique, 2001–2010, from 25.6% (264 out of 1034) to 12.6% (213 out of 1681) in the following next 8 years, 2011–2018, is indicative of the paradigm shift.

There was a significant reduction in both AHI and ESS, the mean decrease in AHI (pre- to post-procedure) was from 35.66 to 13.91 ($p < 0.001$), while the mean decrease in ESS (pre- to post-procedure) was from 11.65 to 5.08 ($p < 0.001$).

The mean AHI change was 22.7 (SD 8.32, range of 4.9 to 36.9) ($p < 0.001$), with mean ESS change 5.8 (SD 2.2, range of 2 to 10) ($p < 0.001$) and mean success rate of 67.5%.

The meta-analysis of the respective palate procedures demonstrated that the surgical procedure that achieved the best AHI reduction was the anterior palatoplasty, with a mean reduction of 24.7 (range 20.79–28.6) ($p = 0.015$), followed by the lateral/expansion pharyngoplasty procedures at a reduction of 19.8 (range 16.90–22.64) ($p = 0.046$), and the least reduction was the classical UPPP, at 17.2 (range 12.68–21.83) ($p = 0.360$).

The authors acknowledge that there are some short-comings with the analysis, (a) although the data presented may be statistically significant, it may not be clinically significant, (b) the patients selected for anterior palatoplasty might have a less difficult anatomy, compared to those in whom a lateral/expansion procedure was done, (c) all these 59 articles are fairly heterogeneous, each article differs in their methodology, (d) these different articles report their data and results differently, (e) different authors have different surgical techniques to address the palate, (f) different nomenclature of palatal procedures will inevitably have some overlap in surgical steps, and, as with most medical literature, there is always a reporter bias (i.e. authors tend to and are more willing to report and publish good results).

The objective of this paper is not to illustrate nor demonstrate the different surgical techniques in the treatment of OSA, but rather to highlight the importance that (1) the efficacy of upper airway surgery has been steadily improving with better airway evaluation techniques, (2) there are innovative, logical yet simple surgical techniques that address the relevant anatomical site of obstruction, that work, and (3) sleep specialists need to continue to attend sleep courses to upgrade themselves and learn new diagnostic and therapeutic methods, in order for their patients to benefit with better success rates.

2.6 Conclusion

The authors highlight that (1) the surgical success rates of upper airway surgery has been steadily improving with the introduction of better airway evaluation techniques, (2) newer innovative surgical techniques can address the relevant anatomical site of obstruction, that work, and (3) there is an obvious shift towards the new generation of palate surgeries and away from the traditional ablative UPPP technique.

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