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The Journal of Dental Panacea

Journal homepage: <https://www.jdentalpanacea.org/>

Review Article

Surgical modalities of obstructive sleep apnea in adults: A systematic review and meta-analysis

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ARTICLE INFO

Article history:

Received 20-10-2022

Accepted 29-10-2022

Available online 24-11-2022

Keywords:

Airway obstruction

Oropharyngeal Surgery

Apneahypopnea Index

ABSTRACT

Obstructive sleep apnea (OSA) is a common condition frequently observed among males aged 40 to 65 years that may lead to early mortality. In the present systematic review, we have looked into the various surgical modalities used for the treatment of OSA and their success on the basis of the pre-operative and post-operative apnea-hypopnea index. The systematic review protocol is registered on the PROSPERO database (Reg ID: CRD42020153323). Studies conducted from June 2000 – June 2020 on OSA patients treated by surgery in the age group of 20-65 years and evaluating the impact of surgery on adult OSA patients were included in the review. Studies were collected from PubMed via MEDLINE, Google Scholar, and Cochrane Central Register of Controlled Trials till June 2020, in accordance with the PRISMA guidelines. A total of 17 articles were identified and two of them were eligible for meta-analysis. According to our meta-analysis, the results indicate that the treatment group had a more beneficial outcome as compared to the control group.

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1. Introduction

Obstructive sleep apnea (OSA) is characterized by loud snoring interspersed with periods of more than ten seconds of silence during sleep.^{1,2} This occurs due to intermittent upper airway collapse or narrowing during sleep leading to hypoxemic and hypercapnic conditions. These may ultimately cause activation of the sympathetic nervous system, excessive daytime sleepiness, and cognitive impairment. Consequently, the patient's quality of life is drastically affected and the risk of developing cardiovascular or endocrinal disorders may lead to early mortality.³

The disorder can affect patients of all age groups and genders,⁴ but the prevalence is highest among males aged 40 to 65 years.⁵ Traditionally, polysomnography (PSG) or

an overnight sleep study in an attended setting such as a sleep laboratory has been used as a reference standard for the diagnosis of OSA.⁶ It determines the apnea-hypopnea index (AHI) which is the number of obstructive airway episodes per hour of sleep. AHI or Respiratory Disturbance Index (RDI)hour is considered $515 \geq 30/\text{hour}$ indicates severe OSA.⁷

Continuous positive airway pressure (CPAP) is currently considered to be the first-line treatment for OSA in adults.⁸ but variable patient compliance is the major drawback of the efficacy of CPAP. Only 30 to 70 % of patients adhere to the CPAP therapy and patients abandon the therapy midway.^{9,10} Owing to the high drop-out rate and intolerance to CPAP, there was a need to seek alternative and more radical treatment modalities.

Surgical treatment of OSA is recommended for patients who have certain anatomical problems (for example,

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enlarged tonsils) or it may be used as a “salvage” treatment option for patients who are not compliant with CPAP. The various surgical modalities for the management of OSA patients include tracheostomy, Uvulopalatopharyngoplasty (UPPP), Uvulopalatoplasty, laser-assisted Uvulopalatoplasty, Maxilla-Mandibular Advancements, Radiofrequency Ablation, Geniohyoid Muscle Advancement along with Hyoid Suspension.

In the present systematic review, we have looked into the various surgical modalities used for the treatment of OSA and their success on the basis of pre-operative and post-operative AHI.

2. Materials and Methods

Studies conducted from June 2000 – June 2020 on OSA patients treated by surgery in the age group of 20-65 years and evaluating the impact of surgery on AHI and RDI on Adult OSA Patients were included. Studies were limited to randomized and non-randomized clinical trials, retrospective studies, and review articles. Descriptive studies, case reports, and series were excluded. The systematic review protocol is registered on the PROSPERO database (Reg ID: CRD42020153323).

2.1. Search strategy

A systematic search was performed across the databases PubMed via MEDLINE, Google Scholar, and Cochrane Central Register of Controlled Trials till June 2020, using the keywords “Sleep Apnea” AND “Surgery.” Cross-references from the included articles were scanned for any additional relevant studies. The overall selection process of the articles is depicted in Figure 1.

2.2. Data extraction

Two groups of authors (AC, SR, and SS, MW) extracted data independently based on the Data Extraction Template from Cochrane Reviews. Any disagreement was resolved by mutual understanding between the authors. Information related to individual study, including the name of the author, country year, description of the population, sample size, study design, method of randomization, intervention, and details of the eligibility criteria were recorded. AHI was the primary outcome measured. The risk of bias in the included studies was evaluated using the Cochrane collaboration’s risk of bias tool. The aspects of included articles that could potentially introduce bias such as randomization, allocation concealment, and blinding were recorded by two independent authors (KW and JL).

2.3. Statistical analysis

Heterogeneity was assessed using Cochrane’s Q and I^2 statistics. Constant continuity corrections of +1 were

performed in case of no events in both test and control groups. Random-effect meta-analysis was performed using the DerSimonian–Laird estimator of variance. As a sensitivity analysis, a fixed-effect meta-analysis was performed using the Mantel–Haenszel method. Risk ratios and 95 % confidence intervals (95 % CI) were calculated as effect estimates. Metanalysis was performed using SPSS v 21.0 (IBM), Epi info v 7.1 (CDC, WHO), Medcalc v 12.5.0.0 (Osteend, Belgium). and GraphPad Prism v. 6.1 and a few online available resources for measuring Heterogeneity and quality checks of individual articles, guidelines like Consort, PRISMA, QUOROM, and MOOSE.

3. Results

The initial search in June 2020 of electronic databases yielded 196 unduplicated articles, which were assessed independently. Based on the abstracts and titles, these were reduced to 17 relevant articles. The main reasons for the exclusion of these articles were lack of clarity of the procedure, study design and outcome, quality issues, and completeness of data.

All the 17 manuscripts identified as relevant to our question were searched for full-text and analyzed for inclusion independently by review authors. Tables 1 and 2 show a summary of the findings of our review. Two manuscripts were relevant for meta-analysis (Figure 2). According to our meta-analysis, the SMD was 0.207, which indicates that the treatment group had a more beneficial outcome as compared to the control group.

4. Discussion

Due to its poor compliance, CPAP is no longer used after a one-year post-prescription. Hence, different surgical modalities for the management of OSA have gained a large footprint with data to support its use. Surgeons also need to consider individual variations in anatomy and also the financial capability of each patient while tailoring their treatment plan. Varying degree be easily performed by surgeons in their routine practice. While each procedure has its own advantages and shortcomings, selecting the most appropriate one is a matter of personal judgment and expertise.¹¹ There is no standard protocol for reconstruction of upper airways accepted by all surgeons globally. Plentiful research has been done in evaluating and comparing different surgical treatment modalities in OSA patients.

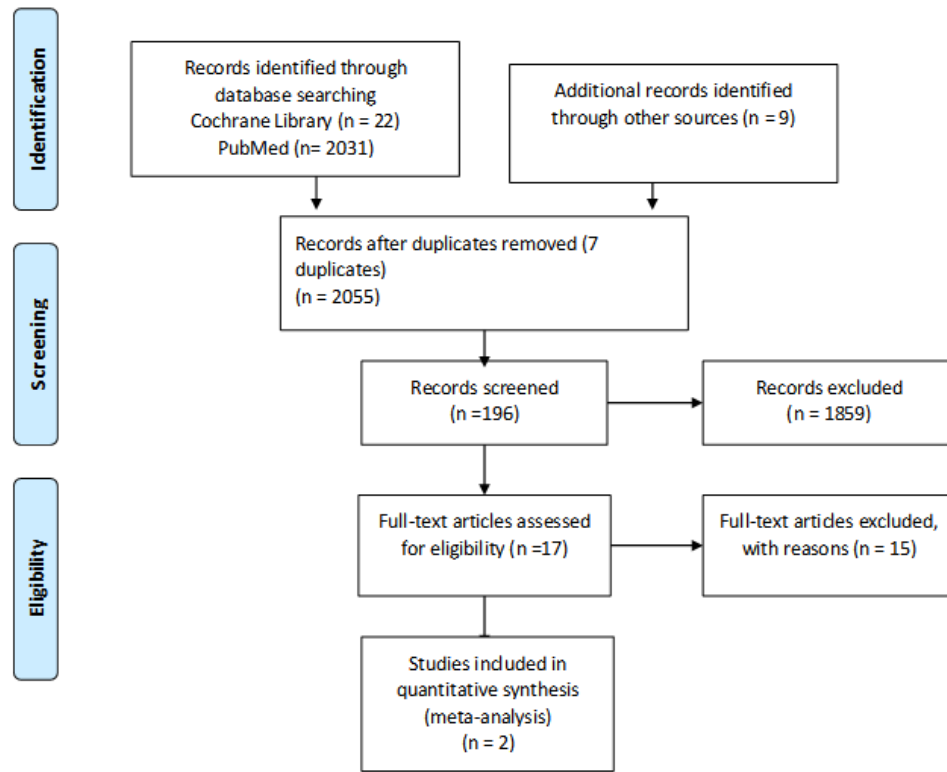


Fig. 1: PRISMA Flow diagram indicating inclusion and exclusion process in the present systematic review and meta-analysis

Table 1: Summary of included studies with baseline characteristics

Author	Year	No. of participants	Severity according to AHI	Severity according to ESS	Duration (weeks)
Aarab	2011	42	Moderate	Moderate	26
Barnes	2004	80	Moderate	Moderate	12
Lam	2007	67	Moderate	Moderate	10
Teixera	2013	19	Moderate	NR	10.5
Duran	2015	42(38)	Mild	NR	12
Schutz	2013	45(25)	Moderate	Moderate	8
Bloch	2000	24	Moderate	Moderate	13
Blanco	2005	24(15)	Severe	Severe	13
Johnston	2002	21(18)	Severe	NR	6
Barnes	2002	42	Moderate	Moderate	8
Tan	2002	24(2)	Moderate	Moderate	8
Glos	2016	40	Severe	NR	24
Engleman	2002	51(48)	Severe	Moderate	8
Gagnadoux	2009	59	Severe	Severe	8
Holley	2011	720(497)	Severe	NR	NR
Marklund	2010	30(19)	Mild	NR	92
Sutherland	2011	39(18)	Moderate	NR	NR
Deane	2009	27	Moderate	NR	20

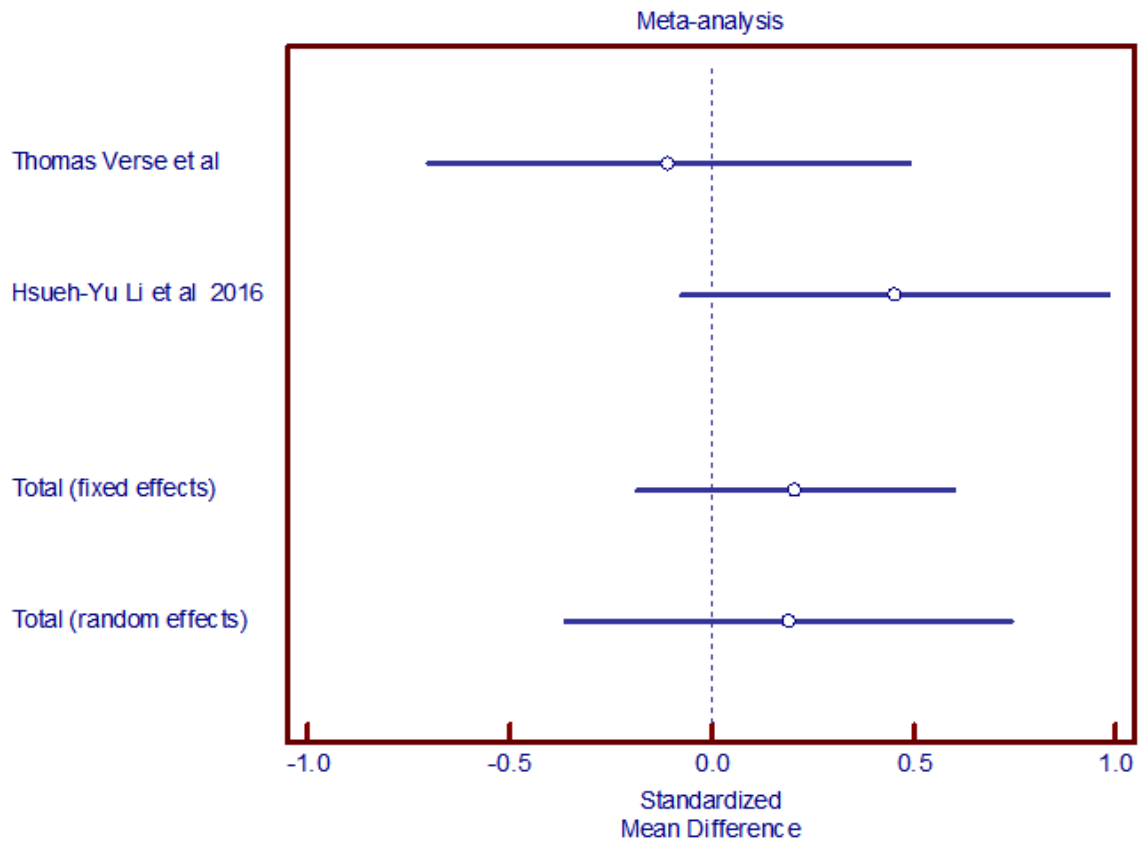


Fig. 2: Meta-analysis of the results of the two eligible studies

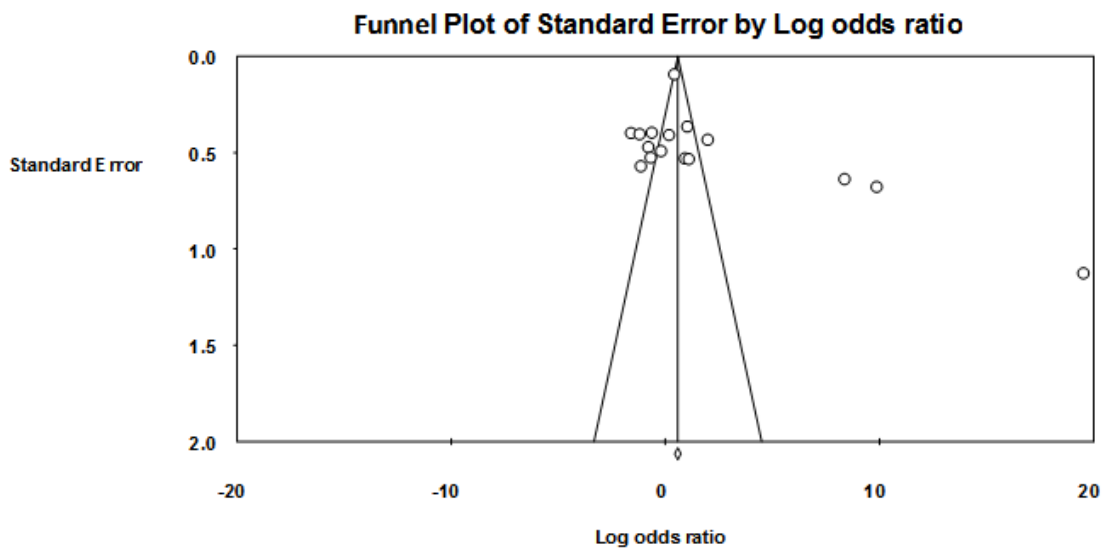


Fig. 3: Funnel plot diagram depicting the risk of possible bias across all the included studies

Table 2: Methods and results of the included studies

S.No.	Author	Year	Country	Type of Study	Comparison Control Group		Methodology	Summary of study
1.	Thomas Verse et al (2000)	2000	USA	Prospective study	11	11	Tonsillectomy was performed, and postoperative complications and polysomnographic findings were reviewed. Follow-up time was 3 to 6 months	Tonsillectomy should be considered an effective and safe surgical option for the treatment of this disorder.
2.	Eric J. Kezirian and Andrew N. Goldberg	2006	US	Systematic review	NA	NA	MEDLINE search of articles or abstracts using the keywords	Hypopharyngeal surgery in obstructive sleep apnea has improved outcomes
3.	Jeffery Prinsel	2002	USA	Systematic review	NA	NA	Protocols of MMA as a primary vs. secondary operation, with and without adjunctive procedures in a site-specific approach, are compared and discussed.	MMA as a potentially definitive primary single-stage surgical treatment of OSAS may result in a significant reduction in OSAS
4.	Thomas Verse et al.	2006	Germany	RCT	Uvula flap, tonsillectomy	A second group did not receive a hyoid suspension	Sixty patients with moderate to severe OSA, nasal surgery was performed. PSG and ESS were recorded at baseline and 2 to 15 months after surgery.	Hyoid suspension proved to be effective in the treatment of OSA.
5.	Adam G Elshaug et al.	2006	Australia	Meta-analysis	NA	NA	A literature search and present interpolated meta-analyses data from 18 surgical articles.	(50% reduction in AHI] and/or ≤ 20) the pooled success rate for Phase I procedures is 55% (45% fail). AHI ≤ 10 , success reduces to 31.5% (68.5% fail) and, at AHI ≤ 5 , success is reduced to 13% (87% fail).
a.	Kourosh Sarkhosh et al.	2013	USA	Systematic review	NA	NA	A total of 69 studies with 13,900 patients. Bariatric procedures [Roux-en-Y gastric bypass, laparoscopic sleeve gastrectomy, or biliopancreatic diversion (BPD)] for treatment of OSA.	For obese individuals with OSA, bariatric surgery remains a viable option in patients with sleep apnea.

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Table 2 continued

b.	Aaron E. Sher	2002	USA	NA	NA	NA	NA	There is no single surgical procedure, short of tracheostomy, which consistently results in the complete elimination of OSAS.
6.	Hsueh-Yu Li et al 4	2016	Taiwan	RCT	Surgical n= 44	Control, n = 22	A total of 66 patients with OSA and chronic nasal obstruction were recruited Nasal surgery alone was the treatment in surgically treated patients.	Results of surgical correction in OSA patients are superior to those who adopted conservative treatment.
7.	Jonathan M. Lee	2012	USA	RCT	NA	NA	drug-induced sleep endoscopy, transoral robot-assisted lingual tonsillectomy with uvulopalatopharyngoplasty, and preoperative and postoperative PSG.	Transoral robot-assisted lingual tonsillectomy with uvulopalato-pharyngoplasty is a novel technique for the surgical management of OSA
8.	Macario Camacho 2014	2014	USA	Systematic review	NA	NA	The searches were performed through June 18, 2014.	Myofunctional therapy decreases AHI by approximately 50% in adults
9.	Bettina Carvalho	2012	USA	Systematic review	NA	NA	Not clear	Not clear
10.	Soroush Zaghi et al	2016	USA	Systematic review	NA	NA	The 4 databases were searched from June 1, 2014, through March 16, 2015.	Maxillomandibular advancement is a highly effective OSA surgical treatment that is associated with substantial improvements
11.	Hsin-Ching Lin		USA	Systematic review	4 groups	NA	Published papers on AHI outcomes of multilevel surgery of the upper airway for OSA were considered	Multilevel upper airway surgery for patients with OSA is associated with improved outcomes.
12.	Song-Tar Toh et al	2014	Singapore	Interventional study	NA	NA	Retrospective review of prospectively collected data in patients with OSA who presented for surgical treatment in Singapore General Hospital.	Transoral robotic surgery for tongue base reduction and partial epiglottidectomy for moderate to severe OSA had good efficacy.

Our meta-analysis compared the pre-operative baseline parameters of various studies and the difference in the post-surgical outcomes. Overall, AHI is significantly improved by surgical treatment of OSA. Kuhlo et al. first described the surgical method for the successful treatment of OSA while Fujita et al. advocated UPPP.^{12,13} The success rate of UPPP was, however, 50% at most. The airway collapsibility resulting in failure of UPPP iobstruction of the tongue base, palate, and hypopharynx.¹⁴ soft palate and base of the tongue a UPPP and Anterior Mandibular Osteotomy with Genioglossus Muscle Advancement and Hyoid Suspension, has yielded successful results in almost all the cases.¹⁵ authors.^{16,17} less than 10.35.¹⁸

OSA is a cumulative result of a complex interaction between multiple factors and thus, the treatment modalities continue to evolve along with an increased understanding of the subject. Aggressive procedures are not preferred by patients or even surgeons, owing to the associated risk of additional morbidity. Various site-specific procedures have been developed as adjuncts to surgery in order to improve the success rate.¹⁹ Multiple sites of obstruction such as nose, palate, lingual tonsils, supraglottic, and tongue base may be present in the patients and can be treated satisfactorily.^{20,21} The ultimate goal is to achieve a large and patent upper airway. There is yet, a paucity of comparative studies assessing the effectiveness of these approaches in correcting the upper airway.

The results of our meta-analysis provided some insight into the superiority of results produced based on the differences achieved in the AHI. However, since the data in all the included studies is quite heterogenous, as indicated by statistical tests, the reliability of this comparison should only be considered with caution. This would imply that even the studies using the same surgical techniques would yield heterogeneous data in terms of measured outcomes. Thus, a potential limitation of our systematic review is the relatively less amount of homogeneous data from included studies.

Although surgical interventions for OSA were introduced more than three decades ago, there are still only a few randomized control trials with long-term clinical follow-up available pertaining to the subject. Without adequate evidence, it may not be possible to determine the mortality rate associated with the different surgical procedures. A mortality rate of 0.2% following Uvulopalatopharyngoplasty was reported by Kezirian et al. in 2004 along with serious postoperative complications in 1.5% of the patients.^{22,23}

A Funnel plot has been included to examine the risks of publication bias across all studies comprising the assessment of AHI using different surgical techniques for the treatment of OSA patients (Figure 3). Overall, there appears to be some bias in the large studies that reported poor treatment outcomes. It may be of use to include data from sources than randomized trials, such as observational studies, when seeking to predict the probability of adverse

effects.

5. Conclusion

In conclusion, the heterogenous and limited nature of studies regarding surgical treatment of OSA renders it difficult to compare their superiority in different aspects such as patient acceptability, success rate, efficiency, and mortality rate. Our meta-analysis indicated that the treatment group had more beneficial outcomes as compared to the control groups across all the different surgical modalities for the treatment of OSA. The surgical procedures would definitely improve the sleep schedule and overall quality of life for OSA patients.

6. Source of Funding

No financial support was received for the work within this manuscript.

7. Conflict of Interest

None declared.

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Cite this article: Chhapane A, Wadde K, Sachdev SS, Landge J, Wadewale M, Rathod S. Surgical modalities of obstructive sleep apnea in adults: A systematic review and meta-analysis. *J Dent Panacea* 2022;4(4):154-161.