Lasers in Medical Science
https://doi.org/10.1007/s10103-020-02987-3

REVIEW ARTICLE

Er:YAG laser for snoring: a systemic review and meta-analysis

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Received: 13 February 2019 / Accepted: 21 February 2020

Abstract

A new outpatient non-surgical method using Er:YAG laser for snoring has been demonstrated. The aim of this systematic review and meta-analysis was to investigate the effects of this treatment on snoring. Relevant 1548 articles were searched from various databases from 1 January 2000 to September 2018 including PubMed, MEDLINE, EMBASE, Cochrane Library, Web of Science, and Scopus and reference lists. Meta-analysis was performed with RevMan software. Cochran's Q and I^2 statistics were used to assess heterogeneity. The overall effect was evaluated using z-tests. Seven studies and two hundred forty-seven participants treated with two to three sessions of Er:YAG 2940 nm laser (long pulse mode, 10 Hz, fluence 1.6 J/cm^2) were included. There was a statistically significant reduction of pooled snoring VAS (mean difference (MD) (95% CI), − 6.89 (− 7.62, − 6.15)). Patient satisfaction rate after laser treatment was 80% (95% CI, 70.69, 89.05) of cases. A widening of the upper airway dimension was revealed; however, changes in apnea-hypopnea index (AHI) and respiratory disturbance index (RDI) were not significantly different. Mean follow-up period was 3 to 36 months. Patients tolerated the procedure well without anesthesia. There were minimal side effects without serious adverse effects. Er:YAG laser is shown to be effective in a way to reduce snoring without significant AHI or RDI changes. However, randomized controlled trials, objective data, multicenter cooperation, and long-term outcomes are needed to confirm the benefits of this laser for snoring.

Keywords Er:YAG laser · Snoring · Obstructive sleep apnea · Laser treatment · Sleep disorders

Introduction

Snoring is generated by soft tissue vibration when the flow of air through the upper airway is partially obstructed during sleep. It affects approximately 40% of men and 20% of women [1, 2]. Several factors cause snoring including nasal congestion, sinus infection, poor muscle tone in the throat and tongue, bulky soft tissue, large tonsils and adenoid, a long soft palate and uvula, upper airway obstruction, obesity, sedative medication, smoking, and alcohol. It is a social problem and may be a potentially risk of sleep deprivation, daytime sleepiness, mood alterations, memory disturbance, headache, dry mouth, lack of focus, irritability, decrease libido, psychological damage, obstructive sleep apnea, vascular diseases, heart attack, and stroke. There are conservative and surgical treatment options for patients with snoring. The conservative treatments include weight control, myofascial exercise, cessation of smoking or alcohol, changing the sleep position, oral tablets or nasal sprays containing different pharmaceuticals, oral appliances, and continuous positive airway pressure (CPAP) [3–12]. Different surgical procedures are available for snoring such as pillar procedure, injection snoreplasty, radiofrequency surgery, laser-assisted uvulopalatoplasty, and other pharyngeal surgery [13–18]. However, patients are still searching for less invasive and more effective options in the treatment of snoring. There was a study showing that an Er:YAG laser causes histological shrinkage of animal palatal mucosa with the absence of carbonization, necrosis, or hemorrhage [19]. Consequently, the airway expanded due to the contraction of the pharyngeal soft tissue. Again, the other study demonstrated that the photothermic effects of this laser significantly increased the airway volume and the minimal cross-section area after treatment in a pilot study of seven patients [20]. Recently, a new outpatient non-surgical method using Er:YAG laser has been shown to be effective in reducing snoring and achieved a certain satisfaction rate as well as improving the quality of sleep and breathing. The main objective of this systemic review and meta-analysis was to

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Published online: 28 February 2020

investigate the effects of Er:YAG laser treatment for patients with snoring and sleep-related breathing disorders. We hypothesize that Er:YAG laser treatment will provide significant improvement in both subjective and objective outcome measures.

Materials and methods

Eligibility criteria and study selection

The studies were included if they met the following criteria: population: patients aged 18 years and older with snoring, sleep apnea, sleep apnoea, and sleep disorder; interventions: Er:YAG treatment; comparison: standard care as control group or pre- and post-treatment; outcomes: snoring score, patient satisfaction, snoring reduction, Mallampati Classification, apnea-hypopnea index (AHI) and respiratory disturbance index (RDI), side effects, and other outcomes such as Friedman Tongue Position, Muller test, and Epworth Sleepiness Scale; and type of design: experimental studies that were either a randomized controlled trial (RCT) or controlled clinical trial (CCT) or prospective/retrospective study which were published in English. We excluded studies if they were qualitative, protocol, or conference papers regarding general sleep apnea populations and current or prior diagnosis of malignancy or other serious medical conditions.

Information source and search strategy

Manual and computerized searches of four databases (MEDLINE, Web of Science, Cochrane Library, and Scopus) were performed from 1 January 2000 to 31 October 2018 to identify all data of relevance. The following keywords and MeSH terms were used (Multimedia Appendix 1): "Er:YAG laser/snoring," "Er:YAG laser/sleep apnea," "Er:YAG laser/sleep apnoea," "Er:YAG laser/disorder," "laser/snoring," "laser/sleep apnea," "laser/sleep apnoea," "laser/sleep disorder," and "treatment/snoring." The cited references in the relevant articles were also reviewed to demonstrate additional published work. Two reviewers (KK: epidemiologist and biostatistician, PS: clinical investigator) performed the literature searches and screening independently, and duplicates were excluded. The senior clinical investigator (CN) developed search strategy, critically reviewed and confirmed the source of the articles. Disagreements between the authors in the study were resolved by consensus.

Selection of studies

Two review authors (KK and CN) independently screened the titles and abstracts of the remaining articles for relevancy and reporting of outcomes of interest. We resolved disagreements through consultation with PS. We retrieved full-text articles of potentially eligible studies. We excluded studies with their reasons for exclusion including duplicate records based on review of titles. We resolved disagreements by discussion with the third review author (PS).

Quality assessment

Two authors (KK and CN) independently checked data to ensure accuracy. Disagreements were resolved by discussion with the third author (PS). The Risk of Bias Assessment tool for Non-randomized Studies (RoBANS) [21] was used to assess the methodology of the studies consisting of a six-item evaluation for each case series. The preferred reporting items for systemic reviews and meta-analysis (PRISMA) statement were followed [22]. The methodology was limited by lack of clear outcomes, prospective, or multicenter cooperation.

Data extraction

Two review authors (KK and CN) independently extracted details of study population, interventions, and outcomes using a standardized data extraction form. For each trial, we extracted at least the following items: publication year, country, sample size, population characteristic such as age and gender, intention-to-treat analysis, adverse events, and reported primary outcome on pre- and post-treatment snoring VAS as well as secondary outcome on patient satisfaction and sleep-related breathing disorders. Moreover, we resolved disagreements in data extraction through consultation with (PS). One author (KK) entered all the extracted data into Review Manager 5. Two review authors (CN and PS) independently checked the accuracy data entry as well as contacted authors of primary studies for missing data.

Data analysis

RevMan software (Review Manager Version 5.3; Cochrane Library Software, Oxford, England) was used for meta-synthesis. Mean difference was used for continuous outcomes estimating the mean and variance from the median and range and proportion rate for categorical outcomes with inverse-variance method [23]. The heterogeneity of studies was performed using Cochran's Q (chi-square test). The statistical significance for heterogeneity using the chi-square test was set as p value < 0.10. Moreover, the percentage of inconsistency index (I^2) was used to describe the total variations in study estimated because of heterogeneity which was estimated using I^2. The Mentel-Haenzel fixed-effect model was used if we found that the studies without significant heterogeneity (p value > 0.10) and the DerSimonian and Laird random effects model was used in studies with heterogeneity of the studies (p value < 0.10 and moderate I^2 (50% and over)). We performed

a statistical power for meta-analysis using Cohen's *d* effect size by considering 0.2, 0.5, and 0.8 as small-, medium-, and large-effect sizes, respectively. As per convention, 80% statistical power was considered sufficient.

Results

Figure 1 shows that the initial electronic search resulted in 1427 titles from the MEDLINE-PubMed, CENTRAL, Scopus database, Cochrane Library, and the Web of Science and 121 additional records identified through other sources. Of these studies, 1475 articles were curated using Endnote to remove duplicates and a total of 73 articles were considered for possible inclusion. Subsequently, 31 articles were removed based on their title and abstract. In all, 42 full-text articles were selected. Of these, 35 articles were excluded because of the studies without sufficient data or are reviews. Finally, seven studies were included in the review.

Study characteristics

The characteristics of seven studies with 247 participants [24–30] are demonstrated in Table 1. All studies were level 4 (case series) evidences. There were no multicenter studies, randomized controlled trials, systematic reviews, or meta-analyses. The summary of risk of bias is shown in Fig. 2. All of the studies had adequate measurements of exposure. However, all studies had inadequate selection of participants, inadequate confirmation and consideration of confounding variables, and inadequate blinding of outcome assessments; one of seven studies had inadequate handling of incomplete outcome data, and five studies had selective reporting of outcomes. The mean age of participants was 44.8 years ranging from 26 to 74 years [26, 28, 29], and most of the participants were males (Table 2).

Snoring scores

The pooled meta-analysis results of two studies reported the change of pre- and post-treatment snoring VAS (1–10) scores [28, 30]. There was statistically significant reduced mean difference in snoring VAS scores (MD (95% CI), −6.89 (−7.62, −6.15)) compared between pre- and post-treatment (Fig. 3), as assessed using the random-effects model (p value < 0.001) and high I^2 values (92.00%). Studies reporting reduction in snoring seemed durable with follow-up ranging from 28 to 36 months [28] and 14 to 24 months [30].

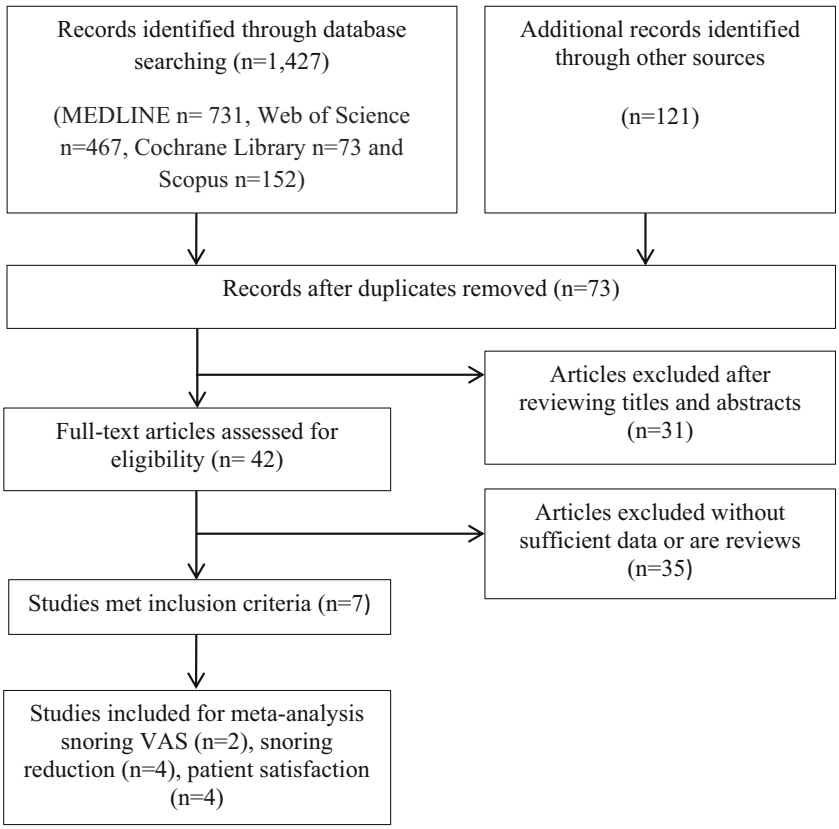

Fig. 1 Preferred reporting items for systematic reviews and meta-analysis (PRISMA) flowchart

Table 1 Patient characteristics

Author [ref]	Sample	Male %	Age	Snoring score Pre and post	ESS Pre and post	Mallampati IV Pre and post	AHI/RDI Mean difference	Patient satisfaction (%)	Snoring reduction (%)
Jovanovic [24]	21	NA	NA (26–59)	NA	NA	NA	NA	NA	62
Dovsak [25]	11	NA	NA	NA	NA	NA	RDI, 4	NA	23
Miracki [26]	57	82.5	44.8 (27–74)	NA	NA	NA	NA	80	50
Svahnstrom [27]	75	NA	NA	NA	NA	1.0	NA	90	NA
Sippus [28]	10	60	45 (30–56)	9.5 (8–10), 2 (1–3)	NA	5/5, 0/5	NA	NA	85
Cetinkaya [29]	33	75	44.3 (28–70)	24.3 (19–29),15.9 (11–21)	NA	NA	NA	65	NA
Storchi [30]	40	NA	51 (43–63.25)	10 (8–10), 3 (1–5)#	4 (2–10), 2 (0–5)*	20/38, 8/38 **	AHI, 1.3	85	NA

ESS, Epworth Sleepiness Scale; *Mallampati*, Mallampati Classification

# $p < 0.001$; * $p < 0.0001$; ** $p = 0.001$

Patient satisfaction

The pooled meta-analysis results of four studies [26, 27, 29, 30] reported that patient satisfaction treatment and outcomes were consistently better after laser treatment. The pooled patient satisfaction rate was 80.00% (95% CI, 70.96, 89.05) of cases (Fig. 4), as assessed using the random-effects model (p value < 0.001) and high I^2 values (100.00%). The follow-up time was in a median of 12 months ranging from 6 to 24 months.

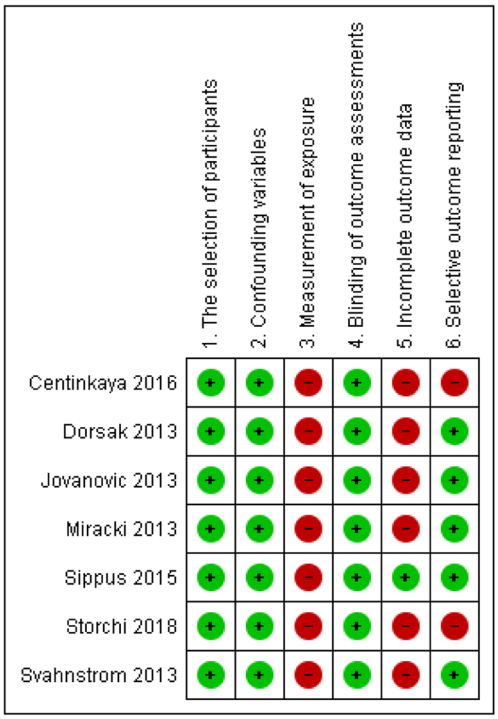

Fig. 2 Risk of bias summary based on The Risk of Bias Assessment tool for Non-randomized Studies (RoBANS)

Mallampati Classification

Three studies reported Mallampati Classification in patients before and after laser treatment. There was an improvement of the airway after the treatment. In the first study, a patient with Mallampati class IV before the treatment changed to class I after the treatment [27]. In the second study, five patients with Mallampati class IV changed to class I or II after the treatment [28]. In the third study, there were 20 and 8 patients out of 38 patients in class IV before and after the treatment, respectively (p value = 0.001) [30].

Apnea-hypopnea index and respiratory disturbance index

Two studies measured respiratory parameters, and one study demonstrated a median AHI at baseline of 16.4 and 15.1 events/h after the treatment in 11 patients with mean difference of − 1.3 events/h with no statistically significant difference (p value = 0.08) [30]. The other study measured RDI in 11 patients and showed a change of RDI within the range of − 35 and 10 events/h after the treatment [25].

Side effects

Side effects included mild sore throat in 2.5 to 3.5%, ceased spontaneously without analgesic treatment [26, 30], temporary altered palatal sensation in 2 out of 33 cases, and brief dry throat or foreign body sensation in 7 out of 33 cases [29]. However, serious adverse effects were not encountered.

Table 2 Study characteristics

Author [ref]	Study design (*n*/size)	Assessment	Protocol	Outcome	Follow-up (months)	Conclusion
Jovanovic [24]	Prospective (21)	Questionnaire	3 sessions (1, 15, 45 days)	Snoring reduction after 1st and 2nd sessions 43 and 62%	9	Snoring reduction
			Uvula, soft palate, and surrounding tissues	Sleep improvement after 1st and 2nd sessions 45 and 68%		Sleep improvement
			Power: NA			
Dovsak [25]	Prospective (11)	Questionnaire	2 sessions (time interval: NA)	Snoring change 23%	3	Snoring time reduction
		PSG	Power: NA	Snoring time reduction 11%		Snoring reduction
		Snoring time		RDI decreased in 4 patients but increased in 7 patients mean difference decreased 4 events/h		No significant RDI change
				Total questionnaire score change 30%		
Miracki [26]	Prospective (57)	Questionnaire	3 sessions (time interval: NA)	Patient satisfaction 80% of cases	3–15	Patient satisfaction
		Mallampati	Anterior pillars, retromolar trigone, check, palate, uvula, tongue, tonsils, posterior pillars	Improvement of snoring severity 50%		Snoring reduction
		Severity of snoring and problems associated with breathing	Power: NA	Respond positively in 74% of patients		Improvement of snoring severity Patients responded positively Mild discomfort No adverse effects Sore throat 3.5%
Svahnström [27]	Prospective (75)	Questionnaire	3 sessions (in a period of 45 days)	Patient satisfaction 90% of cases	6–12	Patient satisfaction
		Mallampati	Anterior pillars, soft palate, tonsils, tongue	Mallampati class IV before treatment decreased to class I after treatment (1 case)		Widening of the airway
		Blood oxygen	Power 12,000–17,000 pulses			No difference in blood oxygen Breathing better, more alert
Sippus [28]	Prospective (10)	Questionnaire	3 sessions (time interval: NA)	Pre- and post-treatment snoring VAS	28–36	Snoring reduction
		Snoring VAS (1–10)	Long pulse mode	Mallampati class IV before treatment decreased to class I or II after treatment (5 cases)		Widening of the airway
		Mallampati	10 Hz			
			Power 10,000–15,000 pulses			
Cetinkaya [29]	Retrospective (33)	Questionnaire	3 sessions (0, 2, 6 weeks)	Patient satisfaction 65% of cases	6–10	Patient satisfaction
		Mallampati	Anterior pillar, soft palate uvula, hard palate, posterior pillars, tonsils	Group I 25–34 years improved snoring score 5.2 ± 1.3		Patient aged ≥ 50 years experienced the best improvement of snoring score
		ESS	Shrinking of mucosa	Group II 35–49 years improved snoring score 7.9 ± 2.2		Mild pain
		Berlin questionnaire	Power 12,000–17,000 pulses	Group III 50–70 years improved snoring score 12.6 ± 2.2		2/33 cases temporary altered palatal sensation
				Groups I and II, $p = 0.954$		7/33 cases reported brief dry throat/foreign body sensation
				Groups III and I, $p = 0.001$		
				Groups III and II, $p = 0.002$		
Storchi [30]	Prospective (40)	Snoring VAS (1–10)	3 sessions (0, 15, 45 days)	Pre- and post-treatment snoring VAS	20 (14–24)	Patient satisfaction
		Muller test	Mucosal surface	Statistically significant changes of Muller test FTP, Mallampati,		Widening of the airway

Table 2 (continued)

Author [ref]	Study design (*n*/size)	Assessment	Protocol	Outcome	Follow-up (months)	Conclusion
				ESS, snoring VAS, restful sleep, difficulty to wake up, dreaming at night, waking up during sleep, dry mouth, and choking		
		FTP Mallampati ESS	Long pulse mode 10 Hz 1.6 J/cm^2	No significant change of AHI		Improvement quality of sleep No change of AHI 12.5% of cases loss of effect at 18.5 months after treatment
		PSG Pain (VAS 0–5)	Power 11,086–25,689 pulses			Mild sore throat 2.5% Less tightness, better breathing

AHI, Apnea-Hypopnea Index; *ESS*, Epworth Sleepiness Scale; *FTP*, Friedman Tongue Position; *Mallampati*, Mallampati Classification; *PSG*, Polysomnography, *RDI*, Respiratory Disturbance Index

Other outcomes

One cohort study reported statistically significant differences in Friedman Tongue Position, Muller test, Epworth Sleepiness Scale, restful sleep, difficulty in waking up, dreaming at night, waking up during sleep, dry mouth, and choking before and after treatment [30].

Subgroup analysis

Two studies performed subgroup analysis, and one demonstrated that elderly patients had better improvement and satisfaction [29] while the other showed that the treatment did not seem to be effective in subjects with laryngeal collapse or subjects with tonsil size over 50% [30].

Treatment

Patients were treated with Er:YAG 2940 nm laser. The parameters were long pulse mode, 10 Hz, and fluence in the range of 1.6 J/cm^2 [28, 30]. The thermal non-ablative heating and tightening was performed on the oropharyngeal mucosa, the soft plate, and the tongue in non-contact mode. The treatment sessions were performed in a period of 45 days in three studies [24, 27, 30] and 6 weeks in one study [29], and the expose time was 20 min [28]. The number of pulses was dependent on the upper airway structure of patients with a median of 15,000 shots ranging from 10,000 to 25,689 shots per session in between two and three sessions [27–30].

Discussion

Snoring is a social problem and may be a precursor to more serious conditions. There are several treatments for snoring; when conservative treatments fail, surgical interventions are performed to reduce, stiffen, and stabilize the upper airway [11, 15, 16]. Non-surgical Er:YAG laser provides a limited depth of penetration, energy absorbed by water, less tissue damage, less edema, less pain, and a proper tool for intraoral use and superficial skin resurfacing [29, 31, 32].

It causes shrinkage of the collagen fibers and subsequently opens up the air flow. The sites of collapse in patient with snoring are uvula, soft palate, lateral pharyngeal walls, and the base of the tongue that can be easily reached by the laser. A study demonstrated that the oropharyngeal airway space significantly increased after the treatment as a result of the photothermic effects [20]. The shrinkage was noticed in the histological examination of the soft palate of the animals which were exposed to this laser using non-contact mode [20]. A low Mallampati Classification, Friedman Tongue Position, and degree of collapse at oropharynx were observed after the treatment and was statistically significant [28, 30].

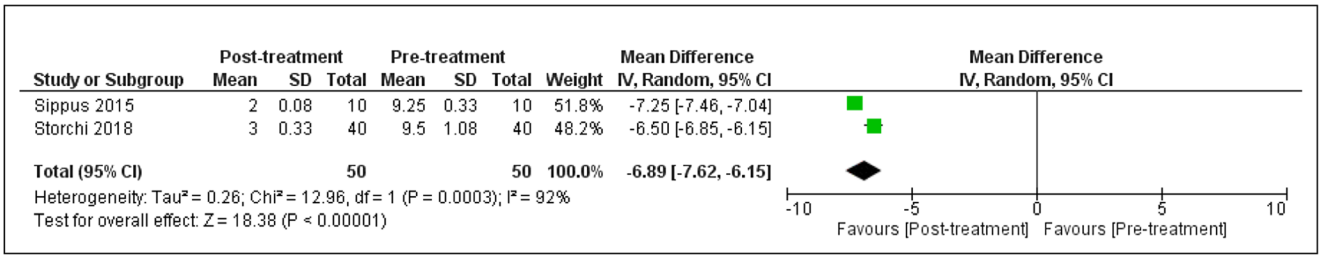

Fig. 3 Forest plot of mean difference in snoring VAS score for pre- and post-laser treatments

The laser produces a wavelength of 2940 nm that is used to tighten the uvula, soft palate, tongue, and surrounding tissue of the upper airway. The shrinkage of collagen and neocollagenesis changes upper airway configuration and consequently reduces snoring and associated problems. The variations in response to the treatment are possibly a consequence of power in the collagen remodeling capacity of each patient, and better outcomes were observed in elderly patients [29].

It requires no device and no anesthesia, involves no chemical treatment, and does not require a sterile operative field. It is easy to perform and has a high success rate in producing a positive change in sleep patterns. It can represent good results for the treatment of snoring, compared with other options. Studies have suggested that up to 80% of patients gain a sufficient benefit from this treatment. The procedure is considered tolerable by majority of patients and quick and easy to perform with a low rate of side effect.

This study showed that many patients responded positively to the laser treatment. It was effective in reducing snoring about half the way from the baseline, and mean difference of pre- and post-treatment was − 6.89 (95% CI, − 7.62, − 6.15). It also improved the quality of sleep in many other sleeping disorder symptoms, and the results were statistically significant. Patients with laryngeal collapse and tonsil size obstructing over 50% of the oropharynx should be excluded from treatment. It raised the subjective quality of sleep, but it did not reduce AHI or RDI. Polysomnography was performed 1 month as a short period after treatment before the neo-collagen was well established such as 2–3 months [30]. There is the need for further study as little number of patients underwent polysomnography after treatment [25, 30].

There are limitations in this study. The evidence level of the included articles was different and results in high risk of bias. Criteria evaluating snoring and other parameters were inconsistent. The selection of symptoms suitable for the treatment was not the same with a lack of control group. The sample size in two studies was small with 10 to 11 cases with the largest size of 75 cases. There is certain heterogeneity. Studies were showing subjective data. Objective measurements on snoring are needed to accurately document the efficacy. A mean follow-up period in this study was 3 to 36 months. Long-term follow-up is necessary to verify the success of the laser treatment. Patient selection with proper examination and exclusion criteria is essential to identify the therapy needed. However, Er:YAG laser treatment reduces snoring at least in a certain period. Long-lasting effects of more than a year allow for high overall satisfaction. The studies included in this present systemic review and meta-analysis show a statistically significant decrease snoring following the treatment.

Conclusions

Non-surgical and minimally invasive treatment with Er:YAG laser is shown to be effective in a statistically significant way to reduce snoring and many other sleep disorder symptoms by widening the upper airway without significant AHI or RDI changes. This laser demonstrated no major side effects

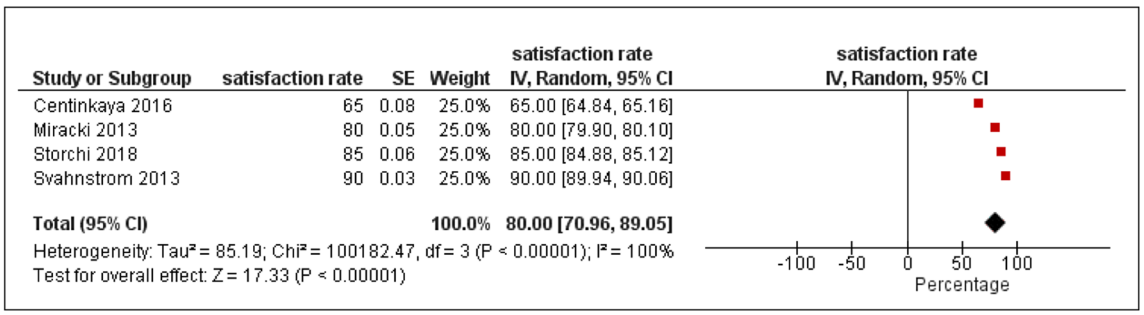

Fig. 4 Forest plot of patient satisfaction rate for post-laser treatment

through long-term follow-up, and the results were sustainable. However, in the future, there still should be more randomized clinical controlled trial with multicenter cooperation and long-term follow-up to evaluate the efficacy of this laser on snoring.

Funding information No funding was received for this research.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethical approval This article does not contain any studies with human and animals participants performed by any of the authors.

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