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Management of primary snoring in adults: A scoping review examining interventions, outcomes and instruments used to assess clinical effects

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Summary

While various treatment options for primary snoring are available, evidence-based recommendations to determine the optimal intervention remain unestablished. To inform future directions of research to guide clinical decision-making, this scoping review was conducted to map the existing evidence on interventions for primary snoring, the outcomes and instruments used to assess their clinical effects in adults. The feasibility of conducting further systematic reviews and comparing outcomes across these therapies using network meta-analysis was also assessed. Of the 1,673 records identified, 38 interventional studies met the inclusion criteria with three-fifths of them being before-after studies. The most common reason for study exclusion was results being reported for patients with primary snoring and obstructive sleep apnoea (OSA) combined. Interventions were surgical (73%), behavioural and the use of devices/medications. Twenty-six common outcomes were identified and categorised into six domains. Fifty-nine instruments were used to assess the outcomes and based mainly on non-validated questionnaires. Our findings indicated (1) the need for randomised controlled trials with strict discrimination between patients with primary snoring and OSA, (2) further network meta-analyses using some outcomes is feasible, and (3) a core outcome set to inform standardised reporting for future research should be developed.

Keywords

Primary snoring, Intervention, Outcome, Instrument, Scoping review, Network meta-analysis

Abbreviations

AASM	American association of sleep medicine
AHI	Apnoea-hypopnoea index
AP	Anterior palatoplasty
CAUP	Cautery-assisted uvulopalatoplasty
CGI-I	Clinical global impression of improvement
CGI-S	Clinical global impression of severity
COS	Core outcome set
CPAP	Continuous positive airway pressure
CT	Computed tomography
DISE	Drug-induced sleep endoscopy
Er:YAG	Erbium-doped yttrium aluminium garnet
ESS	Epworth sleepiness scale
HSAT	Home sleep apnoea test
ICSD	International classification of sleep disorders
ICTRP	International clinical trials registry platform
IS	Injection snoreplasty
JBI	Joanna briggs institute
LAUP	Laser-assisted uvulopalatoplasty
MAD	Mandibular advancement devices
NOSE	Nasal obstruction symptom evaluation
NS	Nasal surgery
OSA	Obstructive sleep apnoea

PCC	Population, concept, context
PI	Palatal implants
PICO	Population, intervention, comparison, outcome
PRISMA	Preferred reporting items for systematic reviews and meta-analyses
PRISMA-ScR	Preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews
PSG	Polysomnography
PSQI	Pittsburgh sleep quality index
RCT	Randomised controlled trial
RDI	Respiratory disturbance index
RF	Radiofrequency
SF-36	36-item short-form health survey
SAT	Snoring assessment table
SBPS	Spouse/bed partner survey
SNORE-25	Symptoms of nocturnal obstruction and related events
SOS	Snore outcome survey
SSI	Snoring symptoms inventory
SSS	Snoring scale score
TBR	Tongue base reduction
TIDieR	Template for intervention description and replication
TMJ	Temporomandibular joints
UPPP	Uvulopalatopharyngoplasty
VAS	Visual analogue scale

Introduction

Primary snoring, also termed isolated snoring, non-apnoeic snoring or simple snoring among other terms, is defined as frequent snoring that occurs without the presence of complete or partial cessation of breathing, i.e. apnoea or hypopnoea, respectively [1]. By this definition, diagnosis with full overnight polysomnography (PSG) or home sleep apnoea test (HSAT), which measures episodes of apnoea and hypopnoea per hour to calculate the apnoea-hypopnoea index (AHI) or the respiratory disturbance index (RDI), is required to differentiate primary snoring from OSA. According to the most recent International classification of sleep disorders-third text revision edition (ICSD-3-TR), primary snoring is classified by an AHI or RDI score of less than five from PSG or HSAT [2].

Snoring is a common sleep condition with estimates of prevalence varying widely depending on the populations studied. According to a systematic review and meta-analysis with 35 included studies, it affects males (2.6–83%) more frequently than females (1.5–71%) with an aggregated odds ratio of 1.89 [3].

Although the majority of primary snorers do not exhibit any pathological health conditions, some studies demonstrated an association between snoring and increased risk of metabolic syndrome [4] and carotid artery atherosclerosis [5,6]. Also, snorers complain of daytime sleepiness due to a poor sleep efficiency, and their bed partners are more likely to suffer from chronic sleep deprivation, which may contribute to morning headaches and mental health impairments [7,8].

In adults, the treatment of primary snoring can generally be categorised either as conservative (non-surgical) or surgical [9,10]. While the range of possible treatment options for primary snoring has grown, evidence-based recommendations to facilitate optimal management of these patients remain unestablished. This may be due to a scarcity of literature synthesising and comparing the different treatments which can be used to guide clinical decision-making.

To explore evidence syntheses in the literature to date, a preliminary search via Ovid MEDLINE was conducted on 22 April 2023 to identify previously published systematic or scoping reviews on the management of primary snoring in the absence of OSA. Of nine articles retrieved, four were not directly related to primary snoring. The other five articles included four systematic reviews reporting on the effectiveness of methods to increase muscle tonus of upper airways [11], radiofrequency ablation of soft palate [12], surgical procedures and non-surgical devices [13], and pharmacological approaches [14] in treatment of snoring. Not only did some of these reviews include combined patients with primary snoring and OSA when the cut-off of AHI or RDI is considered < 5 [12,14], most of them were conducted more than 10 years ago and were reported descriptively without a meta-analysis. Only one identified systematic review conducted a meta-analysis to quantitatively analyse the snoring data between pre- and post-myofunctional therapy [15], although this review evaluated only a single intervention. This preliminary search suggested that there has been no attempt to compare the treatment outcomes of different interventions across studies.

An up-to-date systematic review is therefore required to indicate the most suitable treatments for primary snoring. This could also allow for a network meta-analysis to be carried out, to compare all treatment options across studies for relevant efficacy and safety outcomes. However, in advance of doing that, it is important to have a current map of the available evidence to establish what evaluations of interventions and comparators are possible and what outcome domains and measures are being used to assess its management. Therefore, a scoping review, which enables the examination of existing knowledge, identification of gaps in the literature, and determination of future research priorities related to the topic [16] was undertaken to address this. The individual review questions are:

1. What interventions and comparators have been evaluated to manage patients with primary snoring and their bed partners?

2. What outcomes have been assessed to determine the clinical effects of the management of primary snoring?

3. Which instruments have been used to evaluate clinical outcomes of the management of primary snoring?

This scoping review can also help assess whether a network meta-analysis is feasible by mapping existing evidence and checking whether a connected network of sufficiently homogenous studies reporting the same outcomes can be formed. The results can additionally be used to inform the standardisation of outcome measurement for future research.

Materials and methods

Protocol and registration

The protocol was developed according to the latest guidelines for scoping reviews by the Joanna Briggs institute (JBI) [17] and is available online at the Open science framework (https://osf.io/x3vgp/). The review is reported in accordance with the Preferred reporting items for systematic reviews and meta-analyses extension for scoping reviews (PRISMA-ScR) [18].

Eligibility criteria

The criteria to select studies was formulated based on the population, concept, context, and types of evidence sources [19] as presented in Table 1.

Table 1 Inclusion and exclusion criteria for study selection

	Inclusion criteria	Exclusion criteria
Population	- Adults (aged ≥ 18) with primary snoring defined by AHI or RDI < 5 and their bed partners - Studies that included both patients with primary snoring and those with confirmed diagnosis of OSA were included if they report the outcomes separately for each group - Studies with an unclear or unspecified definition of primary snoring were included and the approach taken reported	- Aged < 18 - Adults (aged ≥ 18) who snore with AHI or RDI ≥ 5 - Studies that included both patients with primary snoring and those with confirmed diagnosis of OSA were excluded if they do not report the outcomes separately for each group
Concept	- Studies that used at least one outcome measure following any management intervention for primary snoring	- Studies on primary snoring without any management intervention and/or without any outcome measure reported
Context	- Outcome measures used to assess the intervention in any setting regardless of geographical or cultural factors	- N/A
Types of evidence sources	- Interventional studies, including randomised, quasi-randomised, non-randomised controlled trials, and before-and-after studies	- Qualitative studies - Animal studies - Case reports - Reviews - Opinion papers - Conference abstracts - Theses, Dissertations

AHI, apnoea-hypopnoea index; OSA, obstructive sleep apnoea; RDI, respiratory disturbance index.

Information sources and search strategy

MEDLINE, Embase, Cochrane Central Register of Controlled Trials, Scopus and Web of Science were searched on 27 June 2023, with a start date 1 January 2000. This start date restriction was applied because the articles published earlier scarcely differentiated primary snoring from OSA [20]. Ongoing trials were additionally searched for via International clinical trials registry platform (ICTRP) and ClinicalTrials.gov. To avoid language bias [21], there were no language restrictions at the searching stage. Reference lists of eligible studies were manually searched for additional relevant articles.

The full search strategy for Ovid MEDLINE advised by a health informatics specialist, is presented in Supplement S1. The alternative search terms for primary snoring were identified in accordance with a previous systematic review [22]. The search strategy was appropriately adapted for the other databases as demonstrated in Supplement S1.

Evidence selection

Results from the electronic searches were imported into Endnote 20 software (Clarivate Analytics, USA), where duplicates were removed. The article selection was performed in two phases. Firstly, two reviewers (CC and NC) independently screened the titles and abstracts of all records. Non-English language articles were screened if English language abstracts were provided. The number of potentially eligible non-English articles was then identified without translating the whole article.

In the second phase, the full text of the relevant studies were evaluated by two independent reviewers based on the eligibility criteria. Reasons for article exclusion were reported. The reference lists of eligible articles were then reviewed. Any disagreement emerging during the two phases in study selection was resolved by discussion between the two reviewers.

Data extraction

A data extraction tool was developed by modifying a template instrument recommended by the JBI [23]. The generated extraction form was first piloted on two included studies (5%), of which one was an RCT and one a before-after study, by two independent reviewers. Subsequently, the team discussed and refined the tool or data to be extracted where necessary until there was team agreement [24].

The extracted data include two types of information from each study: (1) Evidence source details and characteristics, i.e. citation details (authors, year of publication, title, journal, volume, issue, pages), country where the research was conducted, context of the research (aim, setting, diagnosis of primary snoring), participant characteristics (sample size, age, sex) and (2) Specific details relevant to the concept of this scoping review, i.e. research methodology, intervention and comparator descriptions, instruments used to evaluate outcomes, outcomes assessed to determine the clinical effects, timing and length of follow-up. Contacting study authors to obtain additional details when a study did not provide adequate data was not planned. Nevertheless, lack of useable data was described.

Analysis and presentation of the results

As scoping reviews usually do not require advanced analysis methods to address questions of significant effectiveness [25], a descriptive analysis with simple frequency counts was used to demonstrate the number of studies reporting each intervention type, outcome, and measuring instrument. The extracted characteristics were tabulated and explored in a narrative synthesis.

Interventions were divided into non-surgical and surgical approaches. Among the non-surgical methods were: behavioural interventions, e.g. weight loss, sleep positional training, alcohol restriction, smoking cessation, myofuctional therapy; and the use of devices/medications, such as mandibular advancement devices (MAD), and continuous positive airway pressure (CPAP). Surgical methods were classified into two main groups: surgeries for correcting overgrowth of tissues generating snoring sounds, which are more invasive procedures, including various types of uvulopalatopharyngoplasty (UPPP), laser-assisted uvulopalatoplasty (LAUP), tongue base reduction (TBR) and nasal surgery (NS); and surgeries for palatal stiffening, which are less invasive procedures, such as radiofrequency (RF) surgery, palatal implants (PI), injection snoreplasty (IS), and erbium-doped yttrium aluminium garnet (Er:YAG) laser treatment.

Outcome terms were categorised into domains using a standard taxonomy [26] and the instruments were classified according to the outcomes presented. A comprehensive map illustrating the intervention categories, outcome domains and instruments was developed. Lastly, a network diagram was plotted to assess the feasibility of including a network meta-analysis in subsequent systematic reviews. In consistency with guidelines for scoping reviews [17], an assessment of

methodological quality of included sources was not performed due to the nature of the review questions, where biased evidence would not affect the validity of the findings. Therefore, all existing evidence was mapped regardless of its quality.

Results

The selection process is summarised in Figure 1 conforming with the PRISMA 2020 flow diagram [27]. The database searches identified 1,673 records. After duplicates were removed, 737 records remained for title and abstract screening. Eighty-six articles were sought for full-text review, however, two articles were not obtained, 84 full-text articles for screening against the eligibility criteria. More than half of the articles (n=47, 56%) were excluded after full-text screening. The most common reason for exclusion was a combined population of patients with primary snoring and OSA (n=37) due to either study authors not using the cut-off of AHI or RDI < 5 to define primary snoring or non-reporting of outcomes separately for each patient subgroup. Details of articles excluded during full-text screening can be found in Supplement S2.

Manual screening of the reference lists of 37 eligible articles identified one additional study which met the eligibility criteria. Therefore, a total of 38 studies reported in 38 articles were included in final analysis.

Characteristics of included studies

The 38 included studies were from 16 countries. The two countries with the most studies are Turkey (n=9, 24%) and the UK (n=5, 13%). Eleven studies had been conducted in Europe and Scandinavia; three from Germany, two each from the Netherlands, Norway, Finland, and one each from Italy and Cyprus, seven in Asia; two each from Iran, South Korea, Thailand, and one from Taiwan, four in the Americas; two from the USA, and one each from Mexico and Brazil. The remaining two studies were conducted in Egypt.

The 38 included studies were published in the years 2001 to 2023. No studies were published in 2000, 2003, 2020, and 2021 (Figure 2). The average number of published studies over this period was 1.6 per year, with a peak of five studies published in 2006. The number of studies published in the first half of this period was 1.5 times those published in the latter half (n=23, 60% vs n=15, 40%), and the ratio of studies with comparators and without comparators is greater in the first half compared to the latter half (10:13 vs 5:10).

Thirty-two of the 38 included studies (84%) included only patients with a confirmed diagnosis of primary snoring using strict criteria of either AHI or RDI < 5, while the remaining six articles did not specify the diagnosis of primary snoring. These articles are identified by asterisks in Figure 2. It appears that studies with an unspecified diagnosis of primary snoring have been identified in more recent publications ranging from 2008 to 2022 regardless of the study design, including one RCT [28], two non-RCTs [29,30], and three before-after studies [31–33]. The use of drug-induced

sleep endoscopy (DISE) as a method of evaluation of the upper airway of snorers was not found in any of the 38 studies.

The majority of the included articles were before-after studies (n=23, 60%), followed by RCT (n=9, 24%) and non-RCT (n=6, 16%). All of them were published in journal articles except for one ongoing RCT identified from a registry platform [34]. Two of the included RCTs used a crossover design [35,36].

Overall, the studies included 2,174 participants. The median sample size across studies was 50 with the interquartile range (IQR) of 31.5 to 60. The smallest and greatest sample sizes were 18 and 340, respectively. Among the 22 studies (58%) that reported age, the median of the mean age was 41 years (IQR 37 to 44.5), ranging from 18 to 75 years. Among the 31 studies (82%) that reported the number of males and females, the majority of included participants were male with the median percentage of male individuals of 73% (IQR 58% to 81%), ranging from 20% to 100%. The follow-up period varied widely and ranged from 1 day to 8.59 years, although one RCT [28] and one non-RCT [30] did not report when the follow-up was conducted after the intervention.

Tables 2, 3, and 4 summarise key features of the included studies categorised according to their study designs which are RCT, non-RCT, and before-after studies. Studies in each table are presented in chronological order, to help contextualise how research in this field has developed over time.

Interventions

A total of 59 treatment arms were reported in the 38 included studies as some of them are multi-arm trials. Although a wide range of interventions was administered, the treatment arms were predominantly weighted towards surgical approaches (n=43, 73%). Of these surgeries, four surgical procedures accounted for over 80% of the surgical interventions with 17 (39.5%), 7 (16.3%), 7 (16.3%), and 5 (11.6%) arms focusing on RF surgery, PI, UPPP, and LAUP, respectively. Less frequently assessed surgeries included one arm each for TBR, NS, Er:YAG, and four arms (9.3%) for other various surgical approaches.

In terms of the treatment arms evaluating non-surgical approaches (n=13), the most common intervention reported was the use of MAD during sleep (n=5, 38.5%), followed by nasal solution (n=3, 23.1%) and myofunctional exercise (n=3, 23.1%) equally, and sleep positional training (n=2, 15.3%). No studies assessing weight loss, alcohol restriction, smoking cessation, or the use of CPAP, were identified. Among these 59 arms, two arms were a placebo control, while another one arm was a no-intervention control.

All interventions were sub-classified into the intervention category as described in Methods section, i.e. behavioural interventions, the use of devices/medications, surgery for correcting overgrowth of tissues, and surgery for palatal stiffening, and are presented based on their study design in Supplements S3, S4, and S5 for RCT, non-RCT, and before-after study, respectively.

There were 23 treatment arms identified from nine included RCTs. Of these, surgical approach for palatal stiffening was the most commonly evaluated (n=10, 43.5%) with eight arms employed on RF surgery, followed by non-surgical devices/medications (n=5, 21.7%), behavioural interventions (n=3, 13%) and the surgical approach for correcting overgrowth of tissues (n=2, 8.7%). In contrast, of 13 treatments arms identified in six non-RCTs, over three-fifths examined the surgical approach for correcting overgrowth of tissues (n=9, 69.2%) with six arms focusing on UPPP, followed by surgical approach for palatal stiffening (n=3, 23.1%) and the use of MAD (n=1, 7.7%). Among 23 treatment arms identified from 23 before-after studies, over half of the studies assessed the surgical approach for palatal stiffening (n=13, 56.5%), while 26.1% assessed surgical approach for correcting overgrowth of tissues (n=6). The remaining studies evaluated the use of non-surgical devices/medications and behavioural interventions equally (n=2, 8.7% each). Although no behavioural interventions were identified from non-RCTs, they have been evaluated in RCTs and before-after studies ranging from 2015 to 2023.

Table 2 Characteristics and main findings of included randomised controlled trials (n = 9)

Authors and year	Country	Participant	Experimental group		Control group		Outcome measure[#]		
			Intervention	Characteristic	Comparator	Characteristic	Outcome	Instrument	Follow-up
Belloso et al., 2006 [37]	UK	- n = 30 - male = 22 (73%) - age (not reported)	Radiofrequency (RF) coblation	- n = 17 - male = 13 - age = 29-67 (range)	Laser-assisted uvulopalatoplasty (LAUP)	- n = 13 - male = 9 - age = 26-60 (range)	1. Snoring level 2. Pain 3. Analgesic consumption	1. VAS (0-100) (by bed partner) 2. VAS (0-100) 3. Recorded number of doses per day	1. Before / 1w / 2w / 1m / 1y 2. Every day during the first 15d 3. Every day during the first 15d
Cooke et al., 2006 [35]	UK	- n = 23 - male (not reported) - age = 44.7 (median), 29.2-63.5 (range)	Mandibular advancement device (MAD) with advanced position --> with non-advanced position	- not reported	Mandibular advancement device (MAD) with non-advanced position --> with advanced position	- not reported	1. Snoring level 2. Partner sleep quality 3. Daytime sleepiness 4. Quality of life 5. Sleep test: - Snores/hour - Oxygen saturation (%) - AHI 6. Radiographic data: - Post-palatal airway (mm) - Pharyngeal length (mm)	1. VAS (0-10) (by bed partner) 2. 5-Likert scale (by bed partner) 3. Epworth Sleepiness Scale 4. 36-Item Short Form (SF-36) 5. Home sleep apnoea test 6. Cephalome-tric radiography	1. Before / post-phase 1 / post-phase 2 2. Before / post-phase 1 / post-phase 2 3. Before / post-phase 1 / post-phase 2 4. Before / post-phase 1 / post-phase 2 5. Before / post-phase 1 / post-phase 2 6. Before / post-phase 1 / post-phase 2

Authors and year	Country	Participant	Experimental group		Control group		Outcome measure#		
			Intervention	Characteristic	Comparator	Characteristic	Outcome	Instrument	Follow-up
							7. Orofacial discomfort	7. Yes/no questionnaire	7. Post-phase 1 / post-phase 2
Skjostad et al., 2006 [38]	Norway	- n = 20 - male = 12 (60%) - age = 44.1 (mean) 29-61 (range)	Palatal implants (stiffer rigidity 1.8)	- n = 10	Palatal implants (regular rigidity 1.0)	- n = 10	1. Intensity of snoring 2. Daytime sleepiness 3. AHI 4. Side effects: - Pain - Speech - Swallowing difficulties 5. Satisfaction 6. Satisfaction	1. VAS (0-10) (by bed partner) 2. VAS (0-10) 3. Polysomno-graphy 4. VAS (0-10) 5. Yes/no (by snorer) 6. Yes/no (by bed partner)	1. Before / 180d 2. Before / 180d 3. Before / 180d 4. 24h / 72h / 2w / 30d / 90d / 180d 5. 180d 6. 180d
Lim et al., 2007 [39]	South Korea	- n = 44 - male = 34 (77%) - age (not reported)	Radiofrequency-assisted surgery	- n = 24 - male = 18 - age = 37.5 (mean)	Laser-assisted uvulopalatoplasty (LAUP)	- n = 20 - male = 16 - age = 41 (mean)	1. Degree of snoring 2. Daytime sleepiness 3. Pain 4. Foreign body sensation	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. VAS (0-10) 4. Yes/no	1. Before / 6m 2. Before / 6m 3. 1d / 7d / 1w 4. 6m

Authors and year	Country	Participant	Experimental group		Control group		Outcome measure#		
			Intervention	Characteristic	Comparator	Characteristic	Outcome	Instrument	Follow-up
Hirunwiwatkul, 2008 [36]	Thailand	- n = 51 - male = 29 (57%) - age = 20-66 (range)	Xanthane nasal solution --> Placebo	- n = 26 - age = 42.31 ± 11.36 (mean ± SD)	Placebo --> Xanthane nasal solution	- n = 25 - age = 41.04 ± 11.35 (mean ± SD)	1. Severity of snoring sound 2. Nasal complication	1. VAS (0-100) (by bed partner) 2. 5-Likert scale	1. Before / 2w / 4w 2. 2w / 4w
Yoruk et al., 2009 [40]	Turkey	- n = 60 - male = 58 (97%) - age = 38 ± 9 (mean ± SD), 18-45 (range)	Modified radiofrequency-assisted uvulopalatoplasty (MRAUP)	- n = 30	Radiofrequency-assisted uvulopalatoplasty (RAUP)	- n =30	1. Snoring score 2. Speech score 3. Pain at rest 4. Pain during swallowing 5. Analgesic consumption	1. VAS (0-10) (by bed partner) 2. VAS (0-10) 3. VAS (0-10) 4. VAS (0-10) 5. Recorded number of doses per day	1. Before / 1d / 3d / 1m / 6m 2. Before / 1d / 3d / 1m / 6m 3. 1d / 3d / 5d / 7d / 10d 4. 1d / 3d / 5d / 7d / 10d 5. 1d / 3d / 5d / 7d / 10d
Tatar et al., 2014 [41]	Turkey	- n =60 - male = 44 (73%) - age = 43 ± 8 (mean ± SD), 32-51 (range)	Modified radiofrequency-assisted uvulopalatoplasty (MRAUP) + lidocaine	- not reported	MRAUP + lidocaine and dexamethasone / MRAUP + levobupivacaine / MRAUP + levobupivacaine and dexamethasone	- not reported	1. Pain at rest 2. Pain during swallowing 3. Analgesic consumption	1. VAS (0-10) 2. VAS (0-10) 3. Recorded number of doses per day	1. 1d / 3d / 5d / 7d / 10d 2. 1d / 3d / 5d / 7d / 10d 3. 1d / 3d / 5d / 7d / 10d
Sperger et al., 2022 [28]	Brazil	- n = 40 - male = 19 (47.5%) - age (not reported)	Myofunctional therapy for three months	- n = 14 - male = 7 - age = 50.14 ± 9.87 (mean ± SD)	No intervention	- n =26 - male = 12 - age = 50.58 ± 9.29 (mean ± SD)	1. Improvement of snoring 2. Daytime sleepiness 3. Sleep quality 4. Quality of life	1. Yes/no (by bed partner) 2. Epworth sleepiness scale 3. Pittsburgh sleep quality index 4. 36-Item Short Form (SF-36)	1. Before / after 2. Before / after 3. Before / after 4. Before / after

Authors and year	Country	Participant	Experimental group		Control group		Outcome measure[#]		
			Intervention	Characteristic	Comparator	Characteristic	Outcome	Instrument	Follow-up
							5. Objective snore indices	5. SnoreLab smartphone application	5. Before / after
Loerger et al., 2023 [34]	USA	- n = 60 - male (not reported) - age (not reported)	Mandibular Advancement Device (MAD)	- n = 30	Four conservative interventions: - Mometasone nasal rinse - External nasal dilatory therapy - Mouth taping - Lateral positional therapy	- n =30	1. Severity of snoring	1. Clinical Global Impression of Severity (by snorer and bed partner)	1. Before / 4w
							2. Daytime sleepiness	2. Epworth sleepiness scale (by snorer and bed partner)	2. Before / 4w
							3. Symptoms of nocturnal obstruction and related events (SNORE)	3. SNORE-25 (by snorer and bed partner)	3. Before / 4w
							4. Sleep quality and disturbances	4. Pittsburgh Sleep Quality Index (by snorer and bed partner)	4. Before / 4w
							5. Improvement of snoring	5. Clinical Global Impression of Improvement (by snorer and bed partner)	5. 4w

[#] *Outcome measures rated by snorer unless otherwise stated.*

AHI, apnoea-hypopnoea index; VAS, visual analogue scale; d, day; w, week; m, month; y, year.

Table 3 Characteristics and main findings of included non-randomised controlled trials (n = 6)

Authors and year	Country	Participant	Experimental group		Control group		Outcome measure[#]		
			Intervention	Characteristic	Comparator	Characteristic	Outcome	Instrument	Follow-up
Cincik et al., 2006 [42]	Turkey	- n = 54 - male = 38 (70%) - age = 35 (mean), 21-51 (range)	Uvulopalatopharyngoplasty (UPPP)	- n = 18 - male = 12	Two interventions: - Laser-assisted uvulopalatoplasty (LAUP) - Cautery-assisted uvulopalatoplasty (CAUP)	- n = 18 each - male = 13 each	1. Severity of snoring volume 2. Daytime sleepiness 3. Pain	1. Snoring-assessment table (SAT) (by bed partner) 2. Epworth sleepiness scale 3. 4-Likert scale	1. Before / 45d 2. Before / 45d 3. Every week until 45d
Wilson et al., 2006 [43]	UK	- n = 88 - male (not reported) - age (not reported)	Radiofrequency (RF) coblation	- n = 23	Mandibular advancement device (MAD)	- n = 65	1. Snoring score 2. Daytime sleepiness 3. Pain	1. Snoring symptoms inventory (SSI) questionnaire (range 0-100) 2. Epworth sleepiness scale 3. 5-Likert scale	1. Before / 4-6w 2. Before / 4-6w 3. During the first 14 post-operative days
Yang et al., 2008 [29]	South Korea	- n = 58 - male = 49 (84%) - age = 26 (mean) 18-41 (range)	Uvulopalatopharyngoplasty (UPPP) with botulinum toxin type A (BTX-A) injection	- n = 31 - male = 26 - age = 26 (mean)	Uvulopalatopharyngoplasty (UPPP) with normal saline injection	- n = 27 - male = 23 - age = 26 (mean)	1. Snoring score 2. Pain 3. Analgesic consumption 4. Foreign body sensation	1. 5-Likert scale 2. 5-Likert scale 3. Recorded number of doses per day 4. 5-Likert scale	1. Before / 6m 2. 2d / 6d 3. During the first 6 post-operative days 4. 6m

Authors and year	Country	Participant	Experimental group		Control group		Outcome measure[#]		
			Intervention	Characteristic	Comparator	Characteristic	Outcome	Instrument	Follow-up
Cekin et al., 2009 [44]	Turkey	- n = 32 - male = 30 (94%) - age = 37 (mean) 24-55 (range)	Uvulopalatopharyngoplasty (UPPP)	- n = 20	Uvulopalatopharyngoplasty (UPPP) with the uvulopalatal flap (UPF)	- n = 12	1. Snoring level 2. Daytime sleepiness 3. Pain	1. 5-Likert scale (by bed partner) 2. Epworth sleepiness scale 3. 5-Likert scale	1. Before / 90d 2. Before / 90d 3. Every week until 90d
Ugur et al., 2013 [45]	Turkey	- n = 50 - male = 40 (80%) - age (not reported)	Anterior palatoplasty (AP)	- n = 26 - male = 18 - age = 43.2 ± 10.4 (mean ± SD)	Uvulopalatopharyngoplasty (UPPP)	- n = 24 - male = 22 - age = 42.1 ± 11.8 (mean ± SD)	1. Snoring level 2. Daytime sleepiness 3. Pain 4. Satisfaction	1. VAS (0-100) 2. VAS (0-100) 3. VAS (0-100) 4. Yes/no	1. Before / 24m 2. Before / 24m 3. 1d / 3d / 7d / 14d 4. 24m
Woodson et al., 2017 [30]	USA	- n = 20 - male (not reported) - age (not reported)	Radiofrequency ablation of the lateral palatal space	- not reported	Radiofrequency ablation to the inferior turbinates alone	- not reported	1. Snoring loudness 2. Daytime sleepiness 3. Nasal obstruction symptom evaluation (NOSE)	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. NOSE scale (range 0-25)	1. Before / after 2. Before / after 3. Before / after

[#] *Outcome measures rated by snorer unless otherwise stated.*
VAS, visual analogue scale; d, day; w, week; m, month; y, year.

Table 4 Characteristics and main findings of included before-after studies (n = 23)

Authors and year	Country	Participant	Intervention	Outcome measure[#]		
				Outcome	Instrument	Follow-up
Neruntarat, 2001 [46]	Thailand	- n = 340 - male = 311 (91%) - age = 38.3 ± 10.2 (mean ± SD), 19-72 (range)	Laser-assisted uvulopalatoplasty (LAUP)	1. Severity of snoring	1. VAS (0-10) (by bed partner)	1. Before / 6m / long term (mean ± SD = 40.5m ± 5.4m, range 36-50m)
Bäck et al., 2002 [47]	Finland	- n = 20 - male = 19 (95%) - age = 43 (median), 35-63 (range)	Bipolar radiofrequency thermal ablation (bRFTA)	1. Snoring score 2. Snoring score 3. Daytime sleepiness 4. Side effects: - Pain - Swelling sensation - Speaking - Eating	1. VAS (0-10) (by bed partner) 2. VAS (0-10) (by snorer) 3. Epworth sleepiness scale 4. VAS (0-100)	1. Before / 3m / 9.5m 2. Before / 3m / 9.5m 3. Before / 3m / 9.5m 4. 1d / 2d / 3d / 4d / 5d / 6d / 7d after the first treatment and 11d / 12d / 13d / 14d / 15d / 16d / 17d after the second treatment
Wedman et al., 2002 [48]	The Netherlands	- n = 40 - male = 40 (100%) - age (not reported)	Radiofrequency-assisted uvulopalatoplasty (RAUP)	1. Intensity of snoring 2. Sleep quality 3. Daytime sleepiness 4. Pain at rest 5. Pain during swallowing 6. Discomfort level: - Nasal leakage - Foreign body feeling - Speech difference - Taste changes	1. VAS (0-100) (by bed partner) 2. VAS (0-100) 3. VAS (0-100) 4. VAS (0-10) 5. VAS (0-10) 6. VAS (0-100)	1. Before / 3m 2. Before / 3m 3. Before / 3m 4. 1d / 3d / 5d / 7d/ 12d 5. 1d / 3d / 5d / 7d/ 12d 6. 3M
Smith et al., 2004 [49]	UK	- n = 35 - male (not reported) - age = 45 (mean)	Mandibular advancement device (MAD)	1. Daytime sleepiness 2. Sleep study data: - Oxygen saturation (%) - Snoring noise level 3. Orofacial discomfort	1. Epworth sleepiness scale 2. Home sleep apnoea test 3. Yes/no questionnaire	1. Before / 1m 2. Before / 1m 3. 2-3d / 1m

Authors and year	Country	Participant	Intervention	Outcome measure[#]		
				Outcome	Instrument	Follow-up
Maurer et al., 2005 [50]	Germany	- n = 40 - male (not reported) - age = 42.1 ± 9.0 (mean ± SD), 26-61 (range)	Palatal implants	1. Snoring level 2. Daytime sleepiness 3. Sleep parameters: - AHI - RDI - Oxygen saturation 4. Objective snoring index 5. Side effects: - Pain - Swallowing - Speech	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. Polysomnography 4. SNAP-recorder 5. VAS (0-10)	1. Before / 90d / 180d / 360d 2. Before / 90d 3. Before / 90d 4. Before / 90d 5. 90d
Kühnel et al., 2005 [51]	Germany	- n = 99 - male = 79 (80%) - age (not reported)	Palatal implants	1. Severity of snoring 2. Daytime sleepiness 3. Pain	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. VAS (0-10)	1. Before / 30d / 90d / 180d / 360d 2. Before / 30d / 90d / 180d / 360d 3. Not reported
Labra et al., 2008 [52]	Mexico	- n =50 - male = 38 (76%) - age = 18–72 (range)	Uvulopalatopharyngo-plasty (UPPP) with the uvulopalatal flap (UPF)	1. Snoring index (presence and/or volume) 2. Pain	1. Questionnaire (by bed partner) 2. VAS (0-10)	1. Before / 6m 2. 1d / 2d / 3d / 4d / 5d / 6d
Church et al., 2009 [53]	UK	- n = 60 - male (not reported) - age (not reported)	Mandibular advancement device (MAD)	1. Severity of snoring 2. Daytime sleepiness 3. Orofacial discomfort	1. Sleeping partner's evaluation (by bed partner) 2. Epworth sleepiness scale 3. Yes/no questionnaire	1. Before / 3m 2. Before / 3m 3. 2-3d / 1m
Saylam et al., 2009 [54]	Turkey	- n = 21 - male = 12 (57%) - age = 45.7 ± 9.7 (mean ± SD), 31-73 (range)	Palatal implants	1. Severity of snoring 2. Daytime sleepiness 3. Side effects: - Pain - Voice problems - Dysphagia 4. Satisfaction	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. VAS (0-10) 4. VAS (0-100)	1. Before / 30d / 90d / 180d / 360d / 540d 2. Before / 180d / 540d 3. 7d 4. 30d / 90d / 180d / 360d / 540d

Authors and year	Country	Participant	Intervention	Outcome measure[#]		
				Outcome	Instrument	Follow-up
Engelke et al., 2010 [55]	Germany	- n = 125 - male = 101 (81%) - age = males (mean age 52.4, range 34-75), females (mean age 55.2, range 36-70)	Tongue-repositioning manoeuvre (TRM)	1. Snoring loudness	1. VAS (0-10) (by bed partner)	1. Before / last follow-up (mean 4.6m, range 1-16m)
Akpinar et al., 2011 [56]	Turkey	- n = 36 - male = 29 (81%) - age = 39.66 ± 9.32 (mean ± SD), 24-67 (range)	Palatal implants	1. Snoring intensity 2. Daytime sleepiness 3. Satisfaction 4. Improvement	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. Yes/no one question (by bed partner) 4. Yes/no one question (by bed partner)	1. Before / 9m 2. Before / 9m 3. 9m 4. 9m
Li et al., 2011 [57]	Taiwan	- n = 55 - male = 39 (71%) - age = 42 ± 17 (mean ± SD)	Laser-assisted uvulopalatoplasty (LAUP) with Kenalog application	1. Pain	1. VAS (0-100)	1. 1d / 2d / 3d / 7d
Skj Stad et al., 2011 [58]	Norway	- n = 55 - male = 40 (73%) - age = 42.8 (mean), 29-68 (range)	Palatal implants	1. Snoring intensity 2. Daytime sleepiness 3. Satisfaction	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. Yes/no	1. Before / 3y 2. Before / 3y 3. 3y
De Vito et al., 2012 [59]	Italy	- n = 77 - male = 60 (78%) - age (not reported)	Radiofrequency (RF) energy for thermoablation	1. Snoring level	1. VAS (0-10) (by bed partner)	1. Before / minimum 12m
Samimi et al., 2013 [60]	Iran	- n = 35 - male = 7 (20%) - age = 37.8 (mean), 20-65 (range)	Radiofrequency-assisted uvulopalatoplasty (RAUP)	1. Severity of snoring 2. Side effects: - Persistent nasal reflux - Nasal speech	1. VAS (0-10) (by bed partner) 2. Yes/no	1. Before / 3m / 6m / 1y 2. 3m
Naseer et al., 2014 [61]	Egypt	- n = 50 - male = 29 (58%) - age = 40.2 (mean), 28-53 (range)	Modified cautery-assisted palatal stiffening operation (CAPSO)	1. Snoring intensity 2. Daytime sleepiness 3. Oxygen minimum 4. Pain	1. VAS (0-10) (by bed partner) 2. Epworth sleepiness scale 3. Polysomnography 4. VAS (0-10)	1. Before / 3m 2. Before / 3m 3. Before / 3m 4. 2d / 14d
Ertugay et al., 2015 [31]	Turkey	- n = 64 - male = 49 (77%)	Septoplasty	1. Snoring symptom	1. Snore Symptom Inventory (SSI) questionnaire	1. Before / 6m

Authors and year	Country	Participant	Intervention	Outcome measure[#]		
				Outcome	Instrument	Follow-up
		- age = 32.02 ± 10.56 (mean ± SD)		2. Daytime sleepiness 3. Nose obstruction symptom evaluation (NOSE) 4. Side effects: - Nasal complication - Headache	2. Epworth sleepiness scale 3. NOSE scale (range 0-25) 4. VAS (0-10)	2. Before / 6m 3. Before / 6m 4. Before / 1d / 1w / 1 m / 6m
Nemati et al., 2015 [32]	Iran	- n = 53 - male = 32 (60.4%) - age = 45.35 ± 10.08 (mean ± SD), 22-65 (range)	Oropharyngeal-lingual exercises	1. Severity of snoring 2. Severity of snoring	1. VAS (0-10) (by bed partner) 2. Snoring Scale Score (SSS)	1. Before / 1m 2. Before / 1m
Saglam et al., 2016 [62]	Turkey	- n = 28 - male = 15 (54%) - age = 32 ± 9 (mean ± SD), 22-47 (range)	Anterior palatoplasty (AP)	1. Olfactory function test score 2. Retronasal olfactory testing score 3. Gustatory function score 4. Umami sensitivity score	1. Sniffin' sticks orthonasal olfactory testing 2. Identification of odorised powders or granules 3. Taste strip test 4. Umami test solutions	1. Before / 6m 2. Before / 6m 3. Before / 6m 4. Before / 6m
Sinkkonen et al., 2017 [63]	Finland	- n = 77 - male = 42 (54.5%) - age = 44.7 ± 1.7 (mean ± SD)	Soft palate interstitial radiofrequency surgery (SPIRFS)	1. Snoring score 2. Snoring score 3. Bedtime partner wearing earplugs 4. Current snoring condition	1. VAS (0-10) (by bed partner) 2. VAS (0-10) (by snorer) 3. Yes/no (by bed partner) 4. Questionnaire (better / similar / worse than before)	1. Last follow-up (mean 7.35y, range 6.29-8.59y) 2. Last follow-up (mean 7.35y, range 6.29-8.59y) 3. Last follow-up (mean 7.35y, range 6.29-8.59y) 4. Last follow-up (mean 7.35y, range 6.29-8.59y)
Benoist et al., 2018 [64]	The Netherlands	- n = 30 - male = 15 (50%) - age = 41.5 (median), 34.0-51.3 (IQR)	Sleep position trainer (SPT)	1. Severity of snoring 2. Spouse/Bed Partner Survey (SBPS) score 3. Snore Outcome Survey (SOS) score 4. Satisfaction	1. VAS (0-10) (by bed partner) 2. SBPS questionnaire (by bed partner) 3. SOS questionnaire 4. Yes/no	1. Before / 6w 2. Before / 6w 3. Before / 6w 4. 6w
Kazikdas, 2019 [33]	Cyprus	- n = 18 - male = 14 (78%) - age = 33 (median),	Concha radiofrequency surgery	1. Nose obstruction symptom evaluation (NOSE)	1. NOSE scale (range 0-25)	1. Before / minimum 6m (median follow-up 8.3m)

Authors and year	Country	Participant	Intervention	Outcome measure[#]		
				Outcome	Instrument	Follow-up
		22-41 (range)		2. Snoring sound intensity levels (0-100%)	2. SleepBot smartphone application	2. Before / minimum 6m (median follow-up 8.3m)
Kassab et al., 2023 [65]	Egypt	- n = 76 - male = 54 (71%) - age = 60 ± 5 (mean ± SD), 50-70 (range)	Erbium-doped yttrium aluminium garnet (Er:YAG)	1. Snoring level 2. Snoring volume (decibel) 3. Length of soft palate	1. 4-Likert scale (by bed partner) 2. Snorelab smartphone application 3. Computed tomography	1. Before / 6w / 2y 2. Before / 6w / 2y 3. Before / 6w

[#] *Outcome measures rated by snorer unless otherwise stated.*

AHI, apnoea-hypopnoea index; RDI, respiratory disturbance index; VAS, visual analogue scale; d, day; w, week; m, month; y, year.

Outcomes

The outcomes used are presented in Figure 3. While the majority of studies (n=34, 89.5%) reported multiple outcomes, four before-after studies (10.5%) reported a single outcome only [46,55,57,59]. Where studies reported the same outcome using varying terms, they were consolidated under a common term to streamline the reporting process. For instance, subjective measures of snoring, such as snoring level, intensity of snoring, degree of snoring, severity of snoring sound, snoring score, were recorded as subjective snoring level.

Overall, a total of 26 common terms of outcomes were outlined and categorised into six domains. Of the 142 times that these 26 outcomes were assessed, the most evaluated domain was physical function (n=69, 48.6%), followed by adverse events (n=50, 35.2%), delivery of care (n=10, 7%), respiratory outcomes (n=7, 5%), musculoskeletal/connective tissue (n=3, 2.1%) and quality of life (n=3, 2.1%). The top three most frequently assessed outcomes in the 38 studies were subjective snoring level, daytime sleepiness, and pain, which were reported in 32 (84.2%), 20 (52.6%), 18 (47.4%) studies, respectively.

A significant proportion of the 26 outcomes were subjective measures (n=21, 80.8%), whereas only five outcomes (19.2%) were objectively assessed measures, i.e. objective snore measures, oxygen saturation, AHI and/or RDI, length of soft palate, and upper airway space. Among these five outcomes, objective snore measures, e.g. snoring time (minutes) or snoring volume (decibels), in the domain of physical function were most frequently assessed and reported in six studies. Although the number of studies assessing objective outcomes remains substantially smaller

compared to subjective measures of snoring, there has been a recent increase in studies using objective snore measures since half of those six studies were conducted in 2019, 2022, and 2023 [28,33,65].

In terms of follow-up period, outcomes were assessed at varying time points after the intervention across outcome domains. In general, there was a tendency for adverse events to be assessed after relatively short follow-up, ranging from 1 day to 6 months, and the other five domains to be assessed after longer follow-up, ranging from 1 month to 8.59 years.

Of the 26 outcomes presented, there were eight outcomes for which the bed partners were asked to be involved in the evaluation. Figure 4 illustrates the number of studies where outcomes were rated by bed partners and/or snorers. Note that the number of studies when combining those rated by the bed partner and those rated by the snorer together may not add up to the number of studies for that outcome as demonstrated in Figure 3. This is because some studies obtained the results from both snorers and their bed partners for the same outcome. For example, five studies, one RCT [34] and four before-after studies [32,47,63,64], asked both of them to rate subjective snoring level of snorers separately, resulting in a total number of 37 (28 + 9) instead of 32 as shown in Figure 3 for the same outcome.

Although bed partners played an important role in assessing snorer-relevant outcomes, especially subjective snoring level, there were only four outcomes assessed in five included studies which directly aimed to evaluate partner-relevant endpoints, i.e. partners' sleep quality (n=2, 5.3%)

[34,35] and one study each (2.6%) assessing partners' daytime sleepiness [34], partners' wearing earplugs [63], and partners' quality of life [64].

Instruments

Across the 26 outcomes, 59 methods of measurement were used on 152 occasions. The measures were used between 1 and 22 times each. Thirty-three instruments (55.9%) were used only once. Three instruments that were used more than 10 times: the Visual analogue scale (VAS) snoring level rated by bed partners (n=22, 14.5%), the Epworth sleepiness scale (ESS) for assessing daytime sleepiness (n=17, 11.2%) and the VAS for assessing pain (n=14, 9.2%). Table 5 demonstrates the instruments and the frequency of their uses; the sum of uses of instruments for some outcomes may not add up to the number of studies evaluating those outcomes due to several instruments being used to assess one outcome category in individual studies.

The median of the number of instruments used per outcome was 2 (IQR 1 to 3), ranging from 1 to 11 instruments. Twenty-five of the 26 outcomes (96%) were assessed with one to four instruments. Only subjective snoring level was assessed using 11 different instruments. While some of the outcomes appeared to be assessed with a preferred instrument, for example, daytime sleepiness of snorers was mostly assessed using the ESS, subjective snoring level, which was the most frequently reported outcome, was assessed with the greatest variation in measurement methods.

Based on outcome domains, the VAS was the most frequently used instrument in the domain of physical function and adverse events, where most of the outcomes were subjective measures besides the objective snore measures, which were predominantly assessed using smart phone applications. For the domain of respiratory outcomes and musculoskeletal/connective tissue, where their outcomes were completely objective measures, the PSG and cephalometric radiograph were commonly used for assessing sleep parameters and morphological characteristics, respectively. The yes/no answer and SF-36 were often used for assessing the outcomes in the domain of delivery of care and quality of life, respectively.

Table 5 Frequency of the instruments used to assess outcomes

Outcome (number of studies)	Instrument[#]	Type of instrument	Number of uses
Physical function			
Subjective snoring level (n=32)	VAS (by bed partner)	Non-validated Q	22
	VAS	Non-validated Q	3
	Likert scale (by bed partner)	Non-validated Q	2
	Not specified questionnaire (by bed partner)	Non-validated Q	2
	Snoring Symptoms Inventory (SSI)	Validated Q	2
	Clinical Global Impression of Severity (CGI-S)	Validated Q	1
	Clinical Global Impression of Severity (CGI-S) (by bed partner)	Validated Q	1
	Likert scale	Non-validated Q	1
	Snore Outcome Survey (SOS)	Validated Q	1
	Snoring Assessment Table (SAT) (by bed partner)	Validated Q	1
	Snoring Scale Score (SSS)	Validated Q	1
Daytime sleepiness	Epworth Sleepiness Scale (ESS)	Validated Q	17

Outcome (number of studies)	Instrument[#]	Type of instrument	Number of uses
(n=20)	VAS	Non-validated Q	3
Objective snore measures (n=6)	Smart phone application (SnoreLab, Sleepbot)	Objective Measure	3
	Home sleep apnoea test (HSAT)	Objective Measure	2
	SNAP-recorder (a microphone attached system)	Objective Measure	1
Obstruction symptoms (n=4)	Nasal obstruction symptom evaluation (NOSE)	Validated Q	3
	Symptoms of nocturnal obstruction and related events (SNORE-25) (by bed partner)	Validated Q	1
	Symptoms of nocturnal obstruction and related events (SNORE-25)	Validated Q	1
Sleep quality (n=3)	Pittsburgh Sleep Quality Index (PSQI)	Validated Q	2
	VAS	Non-validated Q	1
Partners' sleep quality (n=2)	Likert scale (by bed partner)	Non-validated Q	1
	Pittsburgh Sleep Quality Index (PSQI) (by bed partner)	Validated Q	1
Partners' daytime sleepiness (n=1)	Epworth Sleepiness Scale (ESS) (by bed partner)	Validated Q	1
Partners' wearing earplugs (n=1)	Yes/no (by bed partner)	Non-validated Q	1
Adverse events			
Pain (n=18)	VAS	Non-validated Q	14
	Likert scale	Non-validated Q	4
Speech problems (n=7)	VAS	Non-validated Q	6
	Yes/no	Non-validated Q	1
Swallowing difficulties (n=7)	VAS	Non-validated Q	7

Outcome (number of studies)	Instrument[#]	Type of instrument	Number of uses
Foreign body sensation (n=4)	VAS	Non-validated Q	2
	Likert scale	Non-validated Q	1
	Yes/no	Non-validated Q	1
Nasal complication (n=4)	VAS	Non-validated Q	2
	Likert scale	Non-validated Q	1
	Yes/no	Non-validated Q	1
Analgesic consumption (n=3)	Drug use records	Objective measure	3
Orofacial discomfort (n=3)	Yes/no	Non-validated Q	3
Taste changes (n=2)	VAS	Non-validated Q	1
	Taste strip test	Validated Q	1
	Umami sensitivity test	Validated Q	1
Headache (n=1)	VAS	Non-validated Q	1
Loss of smell (n=1)	Orthonasal olfactory testing	Validated Q	1
	Retronasal olfactory testing	Validated Q	1
Delivery of care			
Satisfaction (n=6)	Yes/no	Non-validated Q	5
	Yes/no (by bed partner)	Non-validated Q	2
Improvement of snoring (n=4)	Yes/no (by bed partner)	Non-validated Q	2
	Yes/no	Non-validated Q	1
	Clinical Global Impression of Improvement (CGI-I)	Validated Q	1
	Clinical Global Impression of Improvement (CGI-I) (by bed partner)	Validated Q	1
Respiratory outcomes			
Oxygen saturation (n=4)	Polysomnography (PSG)	Objective measure	2
	Home sleep apnoea test (HSAT)	Objective measure	2
AHI and/or RDI	Polysomnography (PSG)	Objective measure	2

Outcome (number of studies)	Instrument[#]	Type of instrument	Number of uses
(n=3)	Home sleep apnoea test (HSAT)	Objective measure	1
Musculoskeletal/connective tissue			
Length of soft palate (n=2)	Cephalometric radiograph Computed tomography (CT)	Objective measure Objective measure	1 1
Upper airway space (n=1)	Cephalometric radiograph	Objective measure	1
Quality of life			
Quality of life (n=2)	36-Item Short Form Health Survey (SF-36)	Validated Q	2
Partners' quality of life (n=1)	Spouse/Bed Partner Survey (SBPS) (by bed partner)	Validated Q	1

[#] *Outcome measures rated by snorer unless otherwise stated.*
AHI, apnoea-hypopnoea index; Q, questionnaire; RDI, respiratory disturbance index; VAS, visual analogue scale.

Comprehensive map of interventions, outcomes and instruments

A comprehensive mapping of the instruments relative to intervention categories and outcome domains is illustrated in Figure 5. Because some studies might have used the same instrument for assessing several outcomes in one domain, the number of instruments plotted in each outcome domain may not add up to the sum of uses of instruments in Table 5. For example, a study used the VAS to measure subjective snoring level, sleep quality, and daytime sleepiness in patients who received RF surgery [48]. Thus, in Figure 5, it was counted as one study using VAS in the cell of physical function by surgical approach for palatal stiffening.

Physical function was the most common outcome domain reported in every intervention category with the greatest number in the category of surgical approach for palatal stiffening, although the instruments used to assess them varied across the interventions with the VAS and ESS being most frequently used. Despite a smaller number of studies reported, delivery of care was also evaluated in all intervention categories with the majority of studies using the yes/no answer. Adverse events were assessed in non-surgical devices/medications, surgical approach for correcting overgrowth of tissues and for palatal stiffening with the yes/no question and VAS being most frequently used for non-surgical and surgical approach, respectively. Respiratory outcomes were evaluated in non-surgical devices/medications with HSAT and in surgical approach for palatal stiffening with PSG, whereas musculoskeletal/connective tissue domain was evaluated in similarly both intervention categories with cephalometric radiograph and computed tomography, respectively. Lastly, quality of life was assessed only in non-surgical approaches using SF-36 or SPBS.

According to intervention categories, although 73% of the treatment arms included in this scoping review were surgical approach, quality of life was not assessed in surgical approach for palatal stiffening and three outcome domains, i.e. respiratory outcomes, musculoskeletal/connective tissue, and quality of life were not assessed in surgical approach for correcting overgrowth of tissues. In contrast, all six domains were evaluated in non-surgical devices/medications despite fewer studies. However, adverse events, respiratory outcomes, and musculoskeletal/connective tissue domain were not the focus of non-surgical behavioural interventions. Overall, it indicates that research to date predominantly focuses on surgical approach for palatal stiffening by using the VAS to assess physical function.

Feasibility of conducting a network meta-analysis

The full potential network of interventions is depicted in Figure 6. Of nine RCTs and six non-RCTs included in this scoping review, it was possible to establish a network of connected interventions based on six RCTs and three non-RCTS. The other three RCTs and three non-RCTs were excluded from this feasibility assessment because they typically compared two similar interventions within a trial by performing one of them with a modified procedure.

In the network diagram, each rectangle indicates an active intervention or placebo/no intervention, and each intervention group is represented by a different colour. Comparisons between different interventions are illustrated by blue or red lines according to whether the comparison was made in an RCT or non-RCT, respectively. Overall, nine interventions, including five surgical and four non-surgical approaches, together with placebo and non-intervention controls were included in the network. Restricting the network to RCTs only, MAD, sleep position training, myofunctional exercise, nasal solution, placebo and no intervention can be compared to each other. However, the surgical interventions cannot be compared as these are only connected via the non-RCTs.

While Figure 6 illustrates the best possible scenario for the evidence network comparing the identified interventions, some connections in the network might not be available when different outcomes with specific rating instruments are considered. For instance, a potential network diagram for assessing daytime sleepiness using the ESS as an instrument across studies is depicted in Supplement S6. One RCT comparing RF surgery to LAUP [37] and another RCT comparing nasal solution to placebo [36] were excluded due to no assessment of daytime sleepiness, whereas

one non-RCT comparing UPPP to AP was excluded because daytime sleepiness was assessed using the VAS instead of ESS in this study [45].

Discussion

In the era marked by the availability of diverse treatments for primary snoring, medical practitioners are presented with the challenge of opting for the best-suited therapy weighing the benefits and risks tailored to each individual. To inform the future directions of research for guiding these treatment decisions, this scoping review aimed to examine the current state of evidence regarding the interventions for primary snoring, outcomes and instruments used to assess their clinical effects.

Literature profile

Although the included studies were distributed across the search period (2000 to 2023), the number of studies published in the latter half of this period has declined compared to the first half. This could be attributed to the fact that the sleep medicine community has prioritised the importance of OSA since there was a significant consensus regarding its more serious impact on health conditions and the publication of practice guidelines in 2013 [66]. Compared to OSA, primary snoring has then received less research focus.

Many studies were excluded during full-text screening due to the inclusion of patients with primary snoring in combination with OSA. An AHI/RDI cut-off ranging from 10 to 20 was used when

diagnosing primary snoring in these excluded studies regardless of when they were undertaken. Therefore, there is a clear need for a universal consensus on what AHI or RDI criterion constitutes primary snoring to differentiate benign from malign in terms of health outcomes. In addition, 16% of the included studies did not specify the diagnosis of primary snoring. This group of participants was not excluded because this scoping review attempts to explore all available evidence on the topic, including those characterised by unclear or poor methodology.

The majority of included studies were before-after studies without a remarkable trend to increased numbers of RCTs over time. Along with the small sample sizes of included RCTs ranging from 20 to 60 and non-RCTs ranging from 20 to 88, it has been difficult to draw meaningful comparisons between different interventions across studies. This finding highlights the necessity for researchers to discontinue the execution of small studies without comparators and encourages them to prioritise comparative unbiased studies with sufficient power to assess effectiveness that can impact practical implementation.

In terms of participant demographics, not all included studies reported important factors such as age (58%) and gender (82%). The lack of this information makes it difficult to assess the extent of heterogeneity when pooling findings across studies using meta-analysis because a risk of snoring was found to be significantly higher in males than in females with age being the effect modifier to this association [3]. This finding is thus essential to support complete and transparent reporting in future research, so that possible sources of heterogeneity between studies can be examined and subgroup analyses based on these factors carried out.

Interventions

The majority of treatment arms were heavily weighted towards surgical procedures, although there was a scarcity of studies focusing on the same surgical techniques. Additionally, some surgeries were often performed in a modified manner where their reporting was not always clear on how the procedures were modified. All these reasons have made it difficult to compare across studies. Thus, future research should consider using available reporting guidelines such as the Template for intervention description and replication (TIDieR) checklist to aid in the consistency of reporting on the components of interventions [67].

For non-surgical approaches, MAD was the most frequently assessed. In contrast, although CPAP is considered the gold standard treatment for OSA and has demonstrated the significant inhibition of snoring events in OSA patients, its adherence rate is low in patients with primary snoring [68]. Furthermore, as per the reimbursement policies established in some countries, CPAP is only reimbursed if patients had PSG results showing AHI > 20 [69]. Therefore, these reasons might have led to no evidence on the effect of CPAP in the treatment of primary snoring included in this review, which was restricted to studies in which patients had AHI < 5.

Despite a small number of studies, behavioural interventions, i.e. myofunctional exercise and sleep positional training, have been identified in recent publications ranging from 2015 to 2023. The explanation is probably that since a meta-analysis reported the significant effectiveness of myofunctional therapy for treating OSA in 2015 [70], there has been an increased attempt to evaluate the effect of these economically viable alternatives on primary snoring. However, studies

assessing weight loss, alcohol restriction, smoking cessation were not identified. It is of interest to explore these interventions in future research as they have long been believed as risk factors of snoring and widely advisable for snorers [71].

Outcomes

Due to a range of outcomes found across six domains, especially in the domain of physical function and adverse events, this finding emphasises the ongoing absence of consensus concerning the outcomes used to assess the management of primary snoring. This, in turn, presents challenges in formulating practice recommendations owing to the complexities of pooling heterogeneous data sources.

Regarding physical function, the most frequently assessed outcome was subjective snoring level. Although more objective snore measures have been evaluated in recent identified studies [28,33,65] and it appears that these objective indices, e.g. sound volume, duration, frequency, could potentially aid in evaluating the success of snoring treatments, there is still a lack of standardisation in the use of objective measuring techniques [72]. Moreover, it was claimed that the subjective measurement by the snorer's bed partners has more clinical relevance than those objectively measurable parameters not only because they are the people who suffer from the snoring but also a poor correlation was reported between the subjective and objective measures [73,74]. These justify why the subjective snoring level rated by the bed partner was found as the most common outcome in this scoping review. However, assessment using subjective ratings is susceptible to a risk of bias and solely represents the current partner's snoring perception [75]. It

can therefore be suggested that both types of measurements should be assessed to complement each other in future studies.

There were only four out of the 26 outcomes which focused on assessing the effect on bed partners in response to any intervention received by snorers. Despite the prevalent reports of various adverse consequences caused by sleeping with a snoring individual [7,8], the partners' outcomes were relatively underrepresented in the evaluations included in this scoping review. Because it is usually the concern of snorers about causing negative impacts on their bed partners that motivates them to seek treatment [76], these partner-relevant endpoints should be addressed in future research.

It is surprising that quality of life was one of the least assessed domains. This may reflect the gap between the impact of snoring treatments and an individual's general well-being status from the perspective of researchers. In addition, according to a standard taxonomy [26], no outcomes in the domain of economic resources were assessed. This should be additionally evaluated in future studies to inform practical guidelines on not only efficacy and safety but also affordability.

Instruments

The finding that various instruments were used across each outcome domain emphasises the need for standardisation of outcome measures in correspondence with both research and practice. The most widely used instrument was the VAS. Although the VAS was reported to have good inter-

rater reliability for assessing the snoring subjectively [77], it is uncertain whether the underlying questions used in the included studies involved similar elements of snoring. This would make pooling VAS scores to compare subjective snoring level of different interventions across studies difficult, despite measuring in the same unit.

Besides the ESS [78], other validated questionnaires, e.g. PSQI [79], SSS [80], SOS [81], and SSI [82] were rarely used in the included studies. This could possibly be due to the complexity and length of these questionnaires compared to the VAS. The use of objective snore measures, such as HSAT or smart phone application, is still limited. However, it has been increasing lately because a recent study has validated the mean accuracy rate of 95% of using smart phone application for snoring detection [83]. Therefore, future research should consider including more objective measurement and validated questionnaires to assess the clinical effects of snoring treatments.

Comprehensive map and feasibility of conducting a network meta-analysis

The comprehensive map of the interventions, outcomes and instruments helps thoroughly indicate the areas of available or missing evidence to compare the clinical effects of these treatment options across studies. Generally, it shows that there is a wide range of evaluated outcomes, not only across intervention categories but also within intervention categories. Although the included studies were highly heterogeneous in terms of outcome measures, it seems feasible to conduct a full systematic review with a network meta-analysis for comparing the connected interventions for some specific outcomes that are commonly reported and validated.

Besides a strict similarity assumption in terms of treatment arms and outcome measures, a connected network can become unfeasible if there is heterogeneity in the study design [84]. To estimate the comparative efficacy and safety of multiple therapies across studies, RCTs are the preferred study design, as their rigorous design helps minimise bias, control for confounding variables, and establish stronger causal relationships between treatments and outcomes [85]. However, the networks in Figure 6 and Supplementary S6 would not be fully connected without the non-RCTs and thus leave the comparisons between the surgical approaches and the other interventions impossible. Depending on the defined question, a network of RCTs could be constructed if the review aims to compare only across different non-surgical interventions. In contrast, it is necessary to integrate the non-RCTs if the review question is to compare all identified treatment options across studies, including surgical and non-surgical approaches. However, this consideration should be evaluated in relation to the possibility of causing a greater risk of bias, heterogeneity and inconsistency to the network compared to if only RCTs were included [86].

Although this scoping review found that a network meta-analysis would potentially be feasible using common and validated outcomes, a large variation in utilised outcome measures indicates the need for developing a core outcome set (COS) for this research area. A COS is an agreed set of outcomes that are recommended to be measured and reported as a minimum in all trials of a specific area [87]. This approach helps reduce the heterogeneity in reporting across studies and thereby facilitate future meta-analyses comparing other relevant outcome domains between different interventions for primary snoring.

Limitations

Although there were no language restrictions used at the searching stage and six potentially eligible non-English articles were identified, they were excluded at the stage of full-text screening due to the resource limitations. Because key evidence could have been missed by this restriction which might limit the review's comprehensiveness, the translations should be sourced for these six articles in future systematic reviews on this topic.

Another limitation is that contacting study authors to obtain additional details was not performed when a study did not provide adequate data. The intention in recording information as missing or unclear was to identify the unclear methodology in existing evidence and the need of standardisation for future research. However, this attempt should be made in further systematic reviews.

Lastly, in consistency with guidelines for scoping reviews [17], the included sources of evidence were mapped without undergoing a process of quality appraisal in this review. This could lead to potential bias when evaluating the effectiveness of interventions, which was outside the aims of this scoping review. However, detailed quality assessment is required in further systematic reviews as only relevant evidence with unbiased findings should be pooled in a (network) meta-analysis to inform meaningful practice.

Implications for clinical practice

While implications for clinical practice cannot be directly drawn from the findings of scoping reviews due to the exploratory nature of the review questions and the lack of critical appraisal of included sources of evidence, there are several important recommendations for clinical practice emerging from this review such as the need for a consensus on the cut off for primary snoring diagnosis and agreement on standard outcome measures to assess the management of primary snoring. Employing COS in trials and systematic reviews can support and reinforce the evidence base, leading to enhanced quality of care on a global scale [87]. Although a list of relevant outcomes has been identified through our findings, it is beyond the scope of this review to determine a standardised set of outcomes. Developing a COS requires a further process that involves working with relevant stakeholders of primary snoring interventions, e.g. snorers, bed partners, and clinicians, to prioritise the core set [88].

Conclusions

To our knowledge, this is the first scoping review to demonstrate the breadth of evidence on management of primary snoring by gathering outcomes and instruments used across a variety of interventions and various study designs. The key findings are a comprehensive map of the existing evidence related to the topic, identification of gaps in the literature, and recommendations for further research priorities. In the long run, bringing this information all together may help inform practical guidelines to assist medical practitioners and patients in determining the most suitable treatment for any adult presenting with primary snoring.

Practice points

- The outcome domains and instruments obtained in this scoping review can be used in further development to determine a standardised set of outcomes which are most relevant to the evaluation of the clinical effects of the management interventions for primary snoring.
- A comprehensive mapping of interventions, outcomes and instruments provided in this scoping review will help decrease research waste as researchers can use this information to map out previously covered areas and determine uncovered areas deserving of further investigation.
- A core set of studies that could be incorporated into the full possible network meta-analysis were identified, including nine RCTs and six non-RCTs.

Research agenda

- Since the majority of the included studies were conducted without comparators, there is a clear need for conducting RCTs to compare the efficacy and safety between the different treatments. Moreover, studies with cost-effectiveness analyses should be further undertaken.
- Regarding study reporting, future research should completely report on the essential information such as detailed explanations for treatment procedures and participant characteristics including age and gender. Also, the diagnostic criteria used to specify primary snoring should be clearly indicated.

- Further research should differentiate between primary snoring and snoring as part of OSA, employing the current standards of AHI or RDI < 5 as diagnosed with PSG or HSAT.
- The standardisation of measuring outcomes in this research area should be established to inform standardised reporting in future research.
- The need for developing a COS is highly indicated to facilitate the future conduct of network meta-analyses comparing other relevant outcomes between different interventions across studies.

References

1. Sateia MJ. International classification of sleep disorders-third edition: highlights and modifications. Chest 2014;146:1387–94.

2. American Academy of Sleep Medicine. International classification of sleep disorders, third edition, text revision (ICSD-3-TR) 2023. Available from: https:// https://aasm.org/clinical-resources/international-classification-sleep-disorders/

3. Chan CH, Wong BM, Tang JL, Ng DK. Gender difference in snoring and how it changes with age: systematic review and meta-regression. Sleep Breath 2012;16:977–86.

4. Zou J, Song F, Xu H, Fu Y, Xia Y, Qian Y, et al. The Relationship between Simple Snoring and Metabolic Syndrome: A Cross-Sectional Study. J Diabetes Res 2019;2019:9578391.

5. Lee SA, Amis TC, Byth K, Larcos G, Kairaitis K, Robinson TD, et al. Heavy snoring as a cause of carotid artery atherosclerosis. Sleep 2008;31:1207–13.

6. Kim J, Pack AI, Riegel BJ, Chirinos JA, Hanlon A, Lee SK, et al. Objective snoring time and carotid intima-media thickness in non-apneic female snorers. J Sleep Res 2017;26:147–50.

7. Seidel S, Frantal S, Oberhofer P, Bauer T, Scheibel N, Albert F, et al. Morning headaches in snorers and their bed partners: a prospective diary study. Cephalalgia 2012;32:888–95.

8. Liu Y, Peng T, Zhang S, Tang K. The relationship between depression, daytime napping, daytime dysfunction, and snoring in 0.5 million Chinese populations: exploring the effects of socio-economic status and age. BMC Public Health 2018;18:759.

9. Al-Hussaini A, Berry S. An evidence-based approach to the management of snoring in adults. Clin Otolaryngol 2015;40:79–85.

10. Yaremchuk K. Why and When to Treat Snoring. Otolaryngol Clin North Am 2020;53:351–65.

11. Valbuza JS, Oliveira MM de, Conti CF, Prado LBF, Carvalho LBC de, Prado GF do. Methods to increase muscle tonus of upper airway to treat snoring: systematic review. Arq Neuropsiquiatr 2008;66:773–6.

12. Bäck LJJ, Hytönen ML, Roine RP, Malmivaara AOV. Radiofrequency ablation treatment of soft palate for patients with snoring: a systematic review of effectiveness and adverse effects. Laryngoscope 2009;119:1241–50.

13. Main C, Liu Z, Welch K, Weiner G, Jones SQ, Stein K. Surgical procedures and non-surgical devices for the management of non-apnoeic snoring: a systematic review of clinical effects and associated treatment costs. Health Technol Assess 2009;13:iii, xi–xiv, 1–208.

14. Achuthan S, Medhi B. A systematic review of the pharmacological approaches against snoring: can we count on the chickens that have hatched? Sleep Breath 2015;19:1035–42.

15. Camacho M, Guilleminault C, Wei JM, Song SA, Noller MW, Reckley LK, et al. Oropharyngeal and tongue exercises (myofunctional therapy) for snoring: a systematic review and meta-analysis. Eur Arch Otorhinolaryngol 2018;275:849–55.

16. Munn Z, Peters MDJ, Stern C, Tufanaru C, McArthur A, Aromataris E. Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. BMC Med Res Methodol 2018;18:143.

17. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. JBI Evid Implement 2021;19:3–10.

18. Tricco AC, Lillie E, Zarin W, O'Brien KK, Colquhoun H, Levac D, et al. PRISMA Extension for Scoping Reviews (PRISMA-ScR): Checklist and Explanation. Ann Intern Med 2018;169:467–73.

19. Peters MDJ, Godfrey CM, Khalil H, McInerney P, Parker D, Soares CB. Guidance for conducting systematic scoping reviews. Int J Evid Based Healthc 2015;13:141–6.

20. Hofauer B, Braumann B, Heiser C, Herzog M, Maurer JT, Plößl S, et al. Diagnosis and treatment of isolated snoring-open questions and areas for future research. Sleep Breath 2021;25:1011–7.

21. Pieper D, Puljak L. Language restrictions in systematic reviews should not be imposed in the search strategy but in the eligibility criteria if necessary. J Clin Epidemiol 2021;132:146–7.

22. De Meyer MMD, Jacquet W, Vanderveken OM, Marks LAM. Systematic review of the different aspects of primary snoring. Sleep Med Rev 2019;45:88–94.

23. Peters MDJ, Marnie C, Tricco AC, Pollock D, Munn Z, Alexander L, et al. Updated methodological guidance for the conduct of scoping reviews. JBI Evid Synth 2020;18:2119–26.

24. Pollock D, Peters MDJ, Khalil H, McInerney P, Alexander L, Tricco AC, et al. Recommendations for the extraction, analysis, and presentation of results in scoping reviews. JBI Evid Synth 2023;21:520–32.

25. Levac D, Colquhoun H, O'Brien KK. Scoping studies: advancing the methodology. Implement Sci 2010;5:69.

26. Dodd S, Clarke M, Becker L, Mavergames C, Fish R, Williamson PR. A taxonomy has been developed for outcomes in medical research to help improve knowledge discovery. J Clin Epidemiol 2018;96:84–92.

27. Page MJ, Moher D, Bossuyt PM, Boutron I, Hoffmann TC, Mulrow CD, et al. PRISMA 2020 explanation and elaboration: updated guidance and exemplars for reporting systematic reviews. BMJ 2021;372:n160.

28. Sperger T, Araujo ACF, Soares CF de P. Effect of myofunctional therapy on snoring in obese patients: a randomized trial. Sleep Sci 2022;15:421–8.

29. Yang TY, Jang TY. The effects of one botulinum toxin type A (BTX-A) injection after UPPP. European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery 2008;265:1269–73.

30. Woodson BT, Tadokoro KS, MacKay SG. Radiofrequency ablation of the lateral palatal space for snoring. World journal of otorhinolaryngology - head and neck surgery 2017;3:106–9.

31. Ertugay CK, Toros SZ, Karaca CT, Kulekci S, Verim A, Ertugay OC, et al. Is septoplasty effective on habitual snoring in patients with nasal obstruction?. European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery 2015;272:1687–91.

32. Nemati S, Gerami H, Soltanipour S, Saberi A, Moghadam SK, Setva F. The effects of oropharyngeal-lingual exercises in patients with primary snoring. European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery 2015;272:1027–31.

33. Kazikdas KC. The Perioperative Utilization of Sleep Monitoring Applications on Smart Phones in Habitual Snorers With Isolated Inferior Turbinate Hypertrophy. Ear, nose, & throat journal 2019;98:32–6.

34. Loerger P, Kallogjeri D, Piccirillo JF. Mandibular Advancement vs Home Treatment for Primary Snoring: A Randomized Trial. 2023 [cited 2023 Jul 29];Available from: https://www.ncbi.nlm.nih.gov/pmc/articles/PMC10129709/

35. Cooke M, Battagel J. A thermoplastic mandibular advancement device for the management of non-apnoeic snoring: a randomized controlled trial. European Journal of Orthodontics 2006;28:327-338.

36. Hirunwiwatkul P. Efficacy and adverse effects of Xanthane nasal solution as treatment of primary snoring. Asian Biomedicine 2008;2:189-193.

37. Belloso A, Morar P, Tahery J, Saravanan K, Nigam A, Timms MS. Randomized-controlled study comparing post-operative pain between coblation palatoplasty and laser palatoplasty. Clin. Otolaryngol. 2006;31:138–43.

38. Skjostad KW, Stene BK, Norgard S. Consequences of increased rigidity in palatal implants for snoring: a randomized controlled study. Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery 2006;134:63–6.

39. Lim DJ, Kang SH, Kim BH, Kim HG. Treatment of primary snoring using radiofrequency-assisted uvulopalatoplasty. European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery 2007;264:761–7.

40. Yoruk O, Akgun M, Sutbeyaz Y, Aktan B, Ucuncu H, Tatar A, et al. Treatment of primary snoring using modified radiofrequency-assisted uvulopalatoplasty. European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery 2009;266:1807–14.

41. Tatar AO, Yoruk O, Akgun M. The effects of dexamethasone and levobupivacaine on postoperative pain in modified radiofrequency assisted uvulopalatoplasty (MRAUP) surgery. European archives of oto-rhino-laryngology : official journal of the European Federation of Oto-Rhino-Laryngological Societies (EUFOS) : affiliated with the German Society for Oto-Rhino-Laryngology - Head and Neck Surgery 2014;271:1803–8.

42. Cincik H, Cekin E, Cetin B, Gungor A, Poyrazoglu E. Comparison of uvulopalatopharyngoplasty, laser-assisted uvulopalatoplasty and cautery-assisted uvulopalatoplasty in the treatment of primary snoring. ORL; journal for oto-rhino-laryngology and its related specialties 2006;68:149–55.

43. Wilson JA, Lester SE, Gibson GJ, Anari S, Steele JG, Steen IN, et al. Silencing the snorers: no gain without pain?. The Journal of laryngology and otology 2006;120:570–4.

44. Cekin E, Cincik H, Ulubil SA, Erkul BE, Gungor A. Comparison of uvulopalatopharyngoplasty and uvulopalatal flap in Turkish military personnel with primary snoring. Mil Med 2009;174:432–6.

45. Ugur KS, Kurtaran H, Ark N, Kizilbulut G, Yuksel A, Gunduz M. Comparing anterior palatoplasty and modified uvulopalatopharyngoplasty for primary snoring patients: preliminary results. B-ENT 2013;9:285–91.

46. Neruntarat C. Laser-assisted uvulopalatoplasty: short-term and long-term results. Otolaryngol Head Neck Surg 2001;124:90–3.

47. Bäck LJJ, Tervahartiala PO, Piilonen AK, Partinen MM, Ylikoski JS. Bipolar radiofrequency thermal ablation of the soft palate in habitual snorers without significant desaturations assessed by magnetic resonance imaging. Am J Respir Crit Care Med 2002;166:865–71.

48. Wedman J, Miljeteig H. Treatment of simple snoring using radio waves for ablation of uvula and soft palate: a day-case surgery procedure. Laryngoscope 2002;112:1256–9.

49. Smith AM, Battagel JM. Non-apneic snoring and the orthodontist: the effectiveness of mandibular advancement splints. J Orthod 2004;31:115–23.

50. Maurer JT, Hein G, Verse T, Hörmann K, Stuck BA. Long-term results of palatal implants for primary snoring. Otolaryngol Head Neck Surg 2005;133:573–8.

51. Kühnel TS, Hein G, Hohenhorst W, Maurer JT. Soft palate implants: a new option for treating habitual snoring. Eur Arch Otorhinolaryngol 2005;262:277–80.

52. Labra A, Huerta-Delgado AD, Gutierrez-Sanchez C, Cordero-Chacon SA, Basurto-Madero P. Uvulopalatopharyngoplasty and uvulopalatal flap for the treatment of snoring: technique to avoid complications. J Otolaryngol Head Neck Surg 2008;37:256–9.

53. Church SKJ, Littlewood SJ, Blance A, Gowans AJ, Hodge TM, Spencer RJ, et al. Are general dental practitioners effective in the management of non-apnoeic snoring using mandibular advancement appliances? Br Dent J 2009;206:E15; discussion 416-417.

54. Saylam G, Korkmaz H, Firat H, Tatar EC, Ozdek A, Ardic S. Do palatal implants really reduce snoring in long-term follow-up?. The Laryngoscope 2009;119:1000–4.

55. Engelke W, Engelhardt W, Mendoza-Gartner M, Decco O, Barrirero J, Knosel M. Functional treatment of snoring based on the tongue-repositioning manoeuvre. European journal of orthodontics 2010;32:490–5.

56. Akpinar ME, Yigit O, Kocak I, Altundag A. Does the length of uvula affect the palatal implant outcome in the management of habitual snoring?. The Laryngoscope 2011;121:1112–6.

57. Li LPH, Lee SS, Chuang AYC, Niddam DM, Tung TH, Chen JKC. Dynamic pain after laser-assisted-Uvulo-palatoplasty (LAUP) can instantaneously be mitigated by topical regimens. Lasers in surgery and medicine 2011;43:887–91.

58. Skj Stad KW, Nordg Rd S le. Three-year follow-up of palatal implants for the treatment of snoring. Acta oto-laryngologica 2011;131:1299–302.

59. De Vito A, Frassineti S, Panatta ML, Montevecchi F, Canzi P, Vicini C. Multilevel radiofrequency ablation for snoring and OSAHS patients therapy: long-term outcomes. Eur Arch Otorhinolaryngol 2012;269:321–30.

60. Samimi Ardestani SH, Dadgarnia MH, Baradaranfar MH, Mazidi M, Rabbani M, Behniafard N, et al. Radiofrequency uvulopalatoplasty for primary snoring. Acta medica Iranica 2013;51:530–6.

61. Naseer UA, Khalifa B, Nassar A. Effectiveness of modified cautery-assisted palatal stiffening operation in controlling snoring. Egypt J Otolaryngol 2014;30:147–50.

62. Saglam O, Altundag A, Cayonu M, Salihoglu M, Azizli E, Dursun E, et al. Olfactory and Gustatory Functions after Anterior Palatoplasty in Patients with Primary Snoring. Otolaryngology--head and neck surgery : official journal of American Academy of Otolaryngology-Head and Neck Surgery 2016;154:1155–60.

63. Sinkkonen ST, Ruohoalho J, Pietarinen P, Aaltonen LM, Makitie AA, Back LJ. Limited long-term outcome of single-session soft palate interstitial radiofrequency surgery for habitual snoring in tertiary care academic referral centre: Our experience on 77 patients. Clinical otolaryngology : official journal of ENT-UK ; official journal of Netherlands Society for Oto-Rhino-Laryngology & Cervico-Facial Surgery 2017;42:470–3.

64. Benoist L, Beelen A, Torensma B, de Vries N. Subjective effects of the sleep position trainer on snoring outcomes in position-dependent non-apneic snorers. EUROPEAN ARCHIVES OF OTO-RHINO-LARYNGOLOGY 2018;275:2169–76.

65. Kassab AN, Kharbotly AE, Elsamie AA, Ahmed MR. A Long-Term Follow-up Study for the Treatment of Snoring after Using Patterned Non-Ablative Erbium: YAG 2,940 nm Laser. Int Arch Otorhinolaryngol 2023;27:e104–10.

66. Qaseem A, Holty JEC, Owens DK, Dallas P, Starkey M, Shekelle P, et al. Management of obstructive sleep apnea in adults: A clinical practice guideline from the American College of Physicians. Ann Intern Med 2013;159:471–83.

67. Hoffmann TC, Glasziou PP, Boutron I, Milne R, Perera R, Moher D, et al. Better reporting of interventions: template for intervention description and replication (TIDieR) checklist and guide. BMJ 2014;348:g1687.

68. Counter P, Wilson JA. The management of simple snoring. Sleep Med Rev 2004;8:433–41.

69. Terryn S, De Medts J, Delsupehe K. Comparative Effectiveness of the Different Treatment Modalities for Snoring. Otolaryngol Head Neck Surg 2015;153:468–75.

70. Camacho M, Certal V, Abdullatif J, Zaghi S, Ruoff CM, Capasso R, et al. Myofunctional Therapy to Treat Obstructive Sleep Apnea: A Systematic Review and Meta-analysis. Sleep 2015;38:669–75.

71. Deary V, Ellis JG, Wilson JA, Coulter C, Barclay NL. Simple snoring: Not quite so simple after all? Sleep Medicine Reviews 2014;18:453–62.

72. Arnardottir ES, Isleifsson B, Agustsson JS, Sigurdsson GA, Sigurgunnarsdottir MO, Sigurđarson GT, et al. How to measure snoring? A comparison of the microphone, cannula and piezoelectric sensor. J Sleep Res 2016;25:158–68.

73. Virkkula P, Bachour A, Hytönen M, Malmberg H, Salmi T, Maasilta P. Patient- and bed partner-reported symptoms, smoking, and nasal resistance in sleep-disordered breathing. Chest 2005;128:2176–82.

74. Rohrmeier C, Herzog M, Haubner F, Kuehnel TS. The annoyance of snoring and psychoacoustic parameters: a step towards an objective measurement. Eur Arch Otorhinolaryngol 2012;269:1537–43.

75. Caffier PP, Berl JC, Muggli A, Reinhardt A, Jakob A, Möser M, et al. Snoring noise pollution--the need for objective quantification of annoyance, regulatory guidelines and mandatory therapy for snoring. Physiol Meas 2007;28:25–40.

76. Scott S, Ah-See K, Richardson H, Wilson J a. A comparison of physician and patient perception of the problems of habitual snoring. Clinical Otolaryngology & Allied Sciences 2003;28:18–21.

77. Rohrmeier C, Fischer R, Merz AK, Ettl T, Herzog M, Kuehnel TS. Are subjective assessments of snoring sounds reliable? Eur Arch Otorhinolaryngol 2015;272:233–40.

78. Johns MW. A new method for measuring daytime sleepiness: the Epworth sleepiness scale. Sleep 1991;14:540–5.

79. Buysse DJ, Reynolds CF, Monk TH, Berman SR, Kupfer DJ. The Pittsburgh Sleep Quality Index: a new instrument for psychiatric practice and research. Psychiatry Res 1989;28:193–213.

80. Lim PV, Curry AR. A new method for evaluating and reporting the severity of snoring. J Laryngol Otol 1999;113:336–40.

81. Gliklich RE, Wang PC. Validation of the snore outcomes survey for patients with sleep-disordered breathing. Arch Otolaryngol Head Neck Surg 2002;128:819–24.

82. Douglas SA, Webster S, El Badawey MR, Drinnan M, Matthews JNS, Gibson GJ, et al. The development of a snoring symptoms inventory. Otolaryngol Head Neck Surg 2006;134:56–62.

83. Chiang JK, Lin YC, Lin CW, Ting CS, Chiang YY, Kao YH. Validation of snoring detection using a smartphone app. Sleep Breath 2022;26:81–7.

84. Chaimani A, Caldwell DM, Li T, Higgins JP, Salanti G. Chapter 11: Undertaking network meta-analyses [Internet]. In: Higgins JPT, Thomas J, Chandler J, Cumpston M, Li T, Page MJ, et al., editors. Cochrane Handbook for Systematic Reviews of Interventions. 2019 [cited 2023 Aug 14]. page 285–320.Available from: https://doi.org/10.1002/9781119536604.ch11

85. Bafeta A, Trinquart L, Seror R, Ravaud P. Analysis of the systematic reviews process in reports of network meta-analyses: methodological systematic review. BMJ 2013;347:f3675.

86. Schmitz S, Adams R, Walsh C. Incorporating data from various trial designs into a mixed treatment comparison model. Stat Med 2013;32:2935–49.

87. Williamson PR, Altman DG, Blazeby JM, Clarke M, Devane D, Gargon E, et al. Developing core outcome sets for clinical trials: issues to consider. Trials 2012;13:132.

88. Williamson PR, Altman DG, Bagley H, Barnes KL, Blazeby JM, Brookes ST, et al. The COMET Handbook: version 1.0. Trials 2017;18:280.

Captions to illustrations

Fig. 1. PRISMA flow diagram of the study selection process.

(ICTRP, international clinical trials registry platform; OSA, obstructive sleep apnoea)

Fig. 2. Number of included studies published over time and their study design composition.

(Asterisks indicate studies with an unspecified diagnosis of primary snoring)

Fig. 3. Frequency of the outcomes categorised by outcome domain using a standard taxonomy by Dodd et al (2018).

(AHI, apnoea-hypopnoea index; RDI, respiratory disturbance index)

Fig. 4. Number of studies assessed by bed partners and/or snorers for eight outcomes in which bed partners were asked to rate.

Fig. 5. Comprehensive map illustrating the intervention categories, outcome domains and instruments used in included studies.

(Ceph, cephalometry; CGI-I, clinical global impression of improvement; CGI-S, clinical global impression of severity; CT, computed tomography; Drug, drug use records; ESS, epworth sleepiness scale; HST, home sleep test; NOSE, nasal obstruction symptom evaluation; NotSpec, not specified; ObjSmart, smart phone application; ObjSNAP, SNAP recorder; PSG, polysomnography; PSQI, pittsburgh sleep quality index; SAT, snoring assessment table; SBPS, spouse/bed partner survey; SF-36, 36-item short form health survey; SNORE25, symptoms of nocturnal obstruction and related events; SOS, snore outcome survey; SSS, snoring scale score; Taste, taste test; VAS, visual analogue scale)

Fig. 6. Full potential network of included RCTs and non-RCTs for the feasibility of a network meta-analysis.

Purple boxes indicate behavioural interventions. Blue boxes indicate the use of devices/medications. Red boxes indicate surgical approach for correcting overgrowth of tissues. Orange boxes indicate surgical approach for palatal stiffening. Grey boxes indicate either placebo or no intervention. Blue lines indicate RCTs. Red lines indicate non-RCTs.

(AP, anterior palatoplasty; CAUP, cautery-assisted uvulopalatoplasty; LAUP, laser-assisted uvulopalatoplasty; MAD, mandibular advancement device; RF, radiofrequency surgery; UPPP, uvulopalatopharyngoplasty)