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ORIGINAL ARTICLE

Minimally invasive erbium laser treatment for selected snorers

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Abstract

The aim of this paper is to present our results and experience in the treatment of snoring using the non-ablative Erbium: Yttrium Aluminum Garnet (Er:YAG) laser. Twenty-four patients (18 male and 6 female) with snoring problems due to soft palate hypertrophy were treated with 3 treatment procedures with Er:YAG 2940-nm laser (long pulse mode, 10 Hz, fluence 1.8–2.0 J/cm^2) performed at 2-week intervals. The treatment procedures were performed in outpatient settings. One treatment session lasts 15–20 min. Subjective (questionnaires) and objective (polygraph) outcome measures were assessed at baseline and 3 months after the final laser treatment. Wilcoxon Signed Rank was used to compare before and after scores. All polygraph variables showed some improvement 3 months after the end of treatment; however, only the reduction of the number of hypopnea episodes per hour was statistically significant ($p = 0.034$). In 13/24 patients, snoring time accounted for less than 5% of the sleep time after the treatment compared to 6/24 patients at baseline. The questionnaire survey showed statistically significant improvement in the quality of sleep and life of the patients as well as their partners after Er:YAG treatment ($p < 0.001$). The assessment of daytime sleepiness using the Epworth scale also improved 3 months after the end of treatment ($p = 0.010$). Based on our observations, the treatment of snoring with the Er:YAG laser is an effective and non-invasive therapeutic method. Further studies with long-term follow-up and a control group are warranted to confirm the promising results obtained in case series.

Keywords Snoring · Erbium laser · Non-ablative · Polygraph

Introduction

Snoring is a common term for the acoustic effect that occurs in some individuals during sleep. It is a result of the vibration of flaccid tissues, mainly of the soft palate, the uvula, palatine arches, and partially collapsed pharyngeal walls [1]. The vibration of these tissues is caused by the stream of air passing through the airways. Snoring is both a medical and social problem. In most families, it is an important problem causing a disturbance at night, often being the cause of sleeping in separate beds, and in extreme cases, even the cause of divorce or renouncement of marriage [2]. Snoring affects about 50% of males and 30% of females in the general population. The cause of higher prevalence of snoring in men is not precisely understood. In most cases, patients are not aware of the fact that they snore during sleep. However, they often complain of morning sore throat and a swollen uvula, which gives the feeling of choking and the foreign body sensation [3, 4].

Apart from excessive daytime sleepiness, snoring is the basic symptom of obstructive sleep apnea (OSA) syndrome. Due to the severity of possible complications associated with OSA syndrome, snoring itself seems to be alarming for patients and their environment that should prompt these patients to undergo diagnosis and treatment. The most common reason for seeking help is due to the fact that snoring is not accepted in the society [5].

Treatment of snoring and OSA syndrome includes preventive management (body-weight reduction, avoidance of alcohol, sedative and hypnotic drugs at late hours, proper body position during sleep), conservative treatment (positive airway pressure), and surgery [6–9]. Sprays and tablets available on the pharmaceutical market have no proven efficacy and are not recommended for the treatment of snoring [10, 11].

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In terms of surgery of patients with OSA syndrome, success is obtained when the Apnea-Hypopnea Index (AHI) decreases below 5 after surgery and regression of all symptoms is obtained. This multi-stage, invasive treatment is effective in about 50% of cases. Therefore, appropriate patient selection for surgery is of great importance. The best results are obtained in lean patients with mild and moderate OSA syndrome [5, 12].

Surgical treatment of snoring and OSA syndrome involves various organs in the airways; however, it most often affects the oropharynx. Its history dates back to the 1950s. Ikematsu performed palatopharyngoplasty with partial uvulectomy in 1952 and Fujita introduced uvulopalatopharyngoplasty (UPPP) in 1981. This technique is still used today. However, the procedure requires general anesthesia and is associated with a number of complications [13]. In 1990, Kamami used the CO_2 laser for surgical procedure and performed laser-assisted uvulopalatoplasty (LAUP), which allows tissue reduction of the soft palate under local anesthesia [14]. Intrapalatal procedures, which are definitely less invasive and do not cause damage to a large area of the mucous membrane, were used for the first time in 1997. Their aim is to stiffen the soft palate, which results in reduction of snoring.

Radiofrequency-assisted uvulopalatoplasty is one of these procedures. It consists in inserting a bipolar probe into the tissues of the soft palate for several seconds, using high frequency and low power current. The procedure induces the maximum temperature of 85 °C. As a result, coagulation of adjacent tissues occurs. Scar formation that stiffens the palate is observed in the course of healing. During one treatment session, the probe is entered in 6–8 points in the soft palate under local anesthesia [15, 16]. The Pillar procedure consists in inserting thin implants into the soft palate with single-use tools. Three polyethylene implants are usually placed. Implants with the scar tissue that is formed around them support and stiffen the soft palate, thus reducing the vibration of the soft palate and snoring [17, 18]. Injection snoreplasty is a technique consisting in injecting a sclerosing agent into the soft palate to promote its stiffening. However, the study results are not entirely satisfactory. Frequent allergic reactions and tissue necrosis are reported [19, 20].

All the above surgical procedures are associated with the need for (local or general) anesthesia and the possibility of complications and pain in the postoperative period. In the recent years, there have been studies on the treatment options of respiratory disorders during sleep using the Erbium: Yttrium Aluminum Garnet (Er:YAG) laser [21–23]. This procedure does not require anesthesia and is not associated with pain. The aim of this paper is to present our own results and experience in the treatment of snoring using the Er:YAG laser.

The main aim of this prospective study was to assess the change in the severity of snoring in both subjective (assessed by the patients and their partners) and objective (polygraph test) evaluations. An attempt was also made to assess the change in the quality of sleep and life of the patients. The occurrence of the complications and adverse effects related to the application of the Er:YAG laser was assessed. We hypothesize that non-ablative Er:YAG laser treatment will be tolerable without anesthesia, without serious complications, and provide significant improvement in both subjective and objective outcome measures.

Materials and methods

Study group

The study cohort includes patients who came to our office at Specialist Dental Center CLP A.H. Frelich, Żory, between 14 June 2016 and 18 July 2017 due to snoring. Inclusion criteria was age of 18 years or more, either sex, BMI < 35, absence of systemic disease, and willingness to participate in the study, indicated by signed informed consent. All the patients were examined by an otolaryngologist who carried out endoscopic examinations and assessed the collapse of the airway with the Muller maneuver in the upper respiratory tract. The exclusion criteria were as follows: upper airway obstruction observed during the ENT examination (endoscopy, assessment of nasal patency, Muller's maneuver) that was due to a cause other than soft palate hypertrophy (e.g., nasal septum deviation, hypertrophy of palatine tonsils, hypertrophy of the base of the tongue) (Fig. 1). The patients were qualified into four classes according to Mallampati classification—class 1: visibility of entire soft palate and uvula, class 2: soft palate and upper part of tonsils and uvula are visible, class 3: visibility of soft palate and base of the uvula, and class 4: only hard palate is visible.

Treatment

Plasty of the soft palate with the Er:YAG 2940 nm laser (LightWalker AT, Fotona, Slovenia) was performed in all patients using a PS04 handpiece and collimated beam. The treatment cycle consisted of 3 treatment procedures performed at 2-week intervals. The procedure consists of two phases, i.e., initial and final (Figs. 2 and 3). The initial phase is divided into four stages in which the following areas of the oral cavity and the oropharynx are irradiated: palatoglossal arches, the soft palate with the uvula, palatopharyngeal arches and tonsils, and the lateral region of the tongue and its base. The region of palatoglossal arches is scanned vertically and centrifugally, including the retromolar region and one-third of the posterior region of the cheek. Then, the area of the soft palate with the uvula and the posterior part of the hard palate are scanned. The laser beam is applied in a horizontal direction. Palatopharyngeal arches with the tonsils are irradiated. The laser beam is applied in a vertical direction. For better

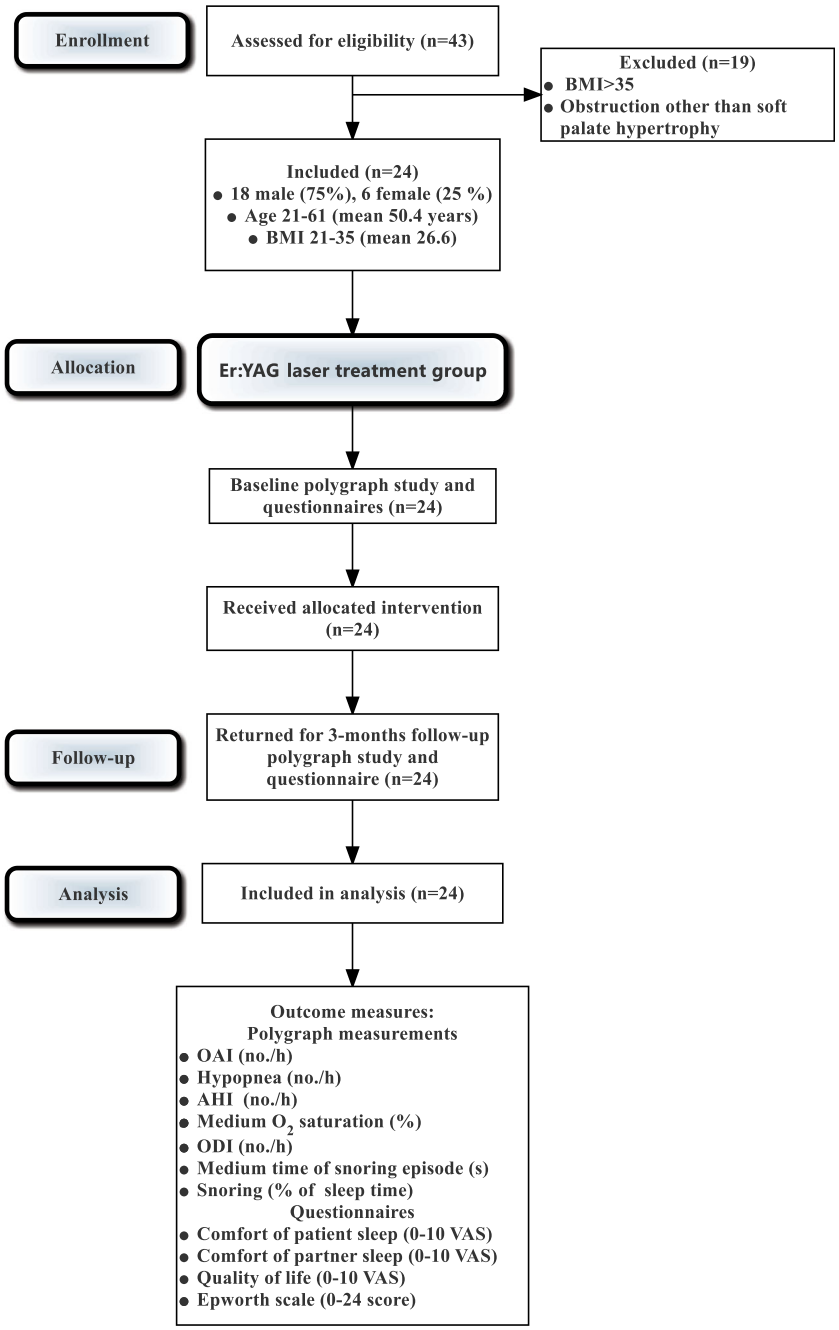

Fig. 1 Study diagram

exposure, the patient is requested to pronounce the "a" vowel. The lateral surfaces of the tongue are irradiated as the final regions in the initial phase. These regions should be visualized using a tongue depressor (Zarys International Group, Zabrze, Poland).

At each stage, the cycle is repeated 7–8 times with a 50% beam overlap of the irradiated region. The beam is delivered in the form of long pulses. The diameter of the spot was 7 mm. The beam with a power of 6.9 W and fluence of 1.8 J/cm^2 was applied. In the final phase, four irradiation cycles are performed with the exception of the tongue surface. However, two additional areas are irradiated, i.e., the region of the uvula and the area of the hard palate, medially from the molars. In this phase, the beam power was increased to 7.75 W, 10 Hz, and fluence to 2 J/cm^2. The number of delivered treatment pulses per session was about 15,000 shots.

The treatment procedures were performed in outpatient settings. One treatment session lasts 15–20 min. No pain was reported by the patients. As a result, anesthesia was not required. The patients were discharged home after a short follow-up of 1–2 h.

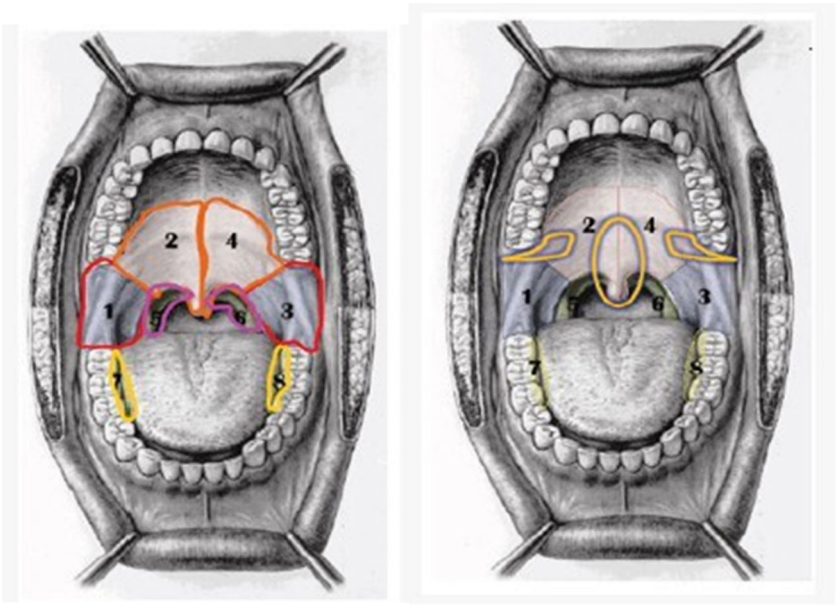

Fig. 2 The initial stage of irradiation: the soft palate with the uvula (2, 4), palatoglossal arches (1, 3), palatopharyngeal arches and tonsils (5, 6), and lateral part of the tongue and its base (7, 8). The final stage of irradiation: the regions of initial irradiation (stages 1–6) and the area marked with a thick yellow line—the region of the uvula and the area of the hard palate, medially from the molars [24]

Outcome measures

Subjective (questionnaires) and objective (polygraph) outcome measures were assessed at baseline and 3 months after the final laser treatment. The quality of sleep and the quality of life of the patient and quality of sleep of the partner were assessed using the 0–10 Visual Analog Scale (VAS) where lower values indicate better sleep and quality of life. The level of daytime sleepiness in the patients was assessed using the 24-point Epworth scale [25]. Values 0–10 are considered normal, and values 11–24 represent increasing levels of "excessive daytime sleepiness."

The polygraph (Alice NightOne®, Philips Respironics, Murrysville, Pennsylvania, USA) measurement was performed at the patients' home one night at baseline and one night 3 months after the last treatment procedure. Polygraph allows an objective assessment of the intensity and time of snoring during sleep and the detection of other respiratory disorders. The polygraph test report contains pulmonary data and information on arterial blood saturation, heart rate, and snoring. The following variables were analyzed: Obstructive Apnea Index (OAI), Hypoapnea index, Apnea – Hypopnea Index (AHI), O_2 saturation (%), Oxygen Desaturation Index (ODI), snoring time (mean duration of episode in s), and percentage snoring time of total sleep time (%).

Statistical analysis

Before and after scores were compared with Wilcoxon Signed Rank Test ($\alpha = 0.05$). Step-wise Bonferroni correction was used to account for multiple comparisons. The effect of patients' sex on the score change was explored with independent *t* tests, but their power was low; a standardized effect size of at least 1.4 would be required for the *t* test to have 80% power to detect the effect at $\alpha = 0.05$. There was no significant effect of sex on the change in any variable and the results for both sexes were reported together. The effect of patients' age and BMI on the score change was explored with correlations. No significant correlation was found between either age or BMI and change from baseline of any variable. All analyses were performed with IBM SPSS Statistics 20 (SPSS Inc., Chicago, USA).

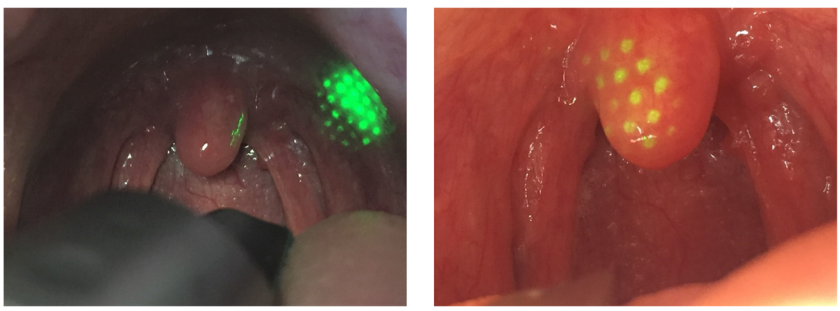

Fig. 3 Intraoperative image

Results

The study included 24 patients (18 men and 6 women) aged 21–61 (mean 50.4) years. Mean BMI was 26.6 ± 3.7 (range 21–35) (Fig. 1). According to Mallampati scale, 6 of the patients were classified as class 4, 3 patients as class 3, 9 as class 2, and 6 as class 1. Baseline values of all outcome measures are listed in Table 1.

All polygraph variables (OAI, Hypoapnea index, AHI, O_2 saturation, ODI, snoring time, and percentage snoring time of total sleep time) showed some improvement 3 months after the end of treatment; however, only the reduction of the number of hypopnea episodes per hour was marginally statistically significant (Table 1, Fig. 4). Three months after treatment, 3 patients had normal breathing (AHI < 5), 13 had mild (AHI 5–15), 5 moderate (AHI 15–30), and 3 severe SDB (AHI ≥ 30). Seven patients increased their SDB severity by 1 grade, 7 patients remained in the same grade, 9 patients improved by 1 grade, and 1 patient improved by 2 grades compared to baseline severity. In 13/24 patients, snoring time accounted for less than 5% of the sleep time after the treatment compared to 6/24 patients at baseline (Fig. 4).

The questionnaire survey showed statistically significant improvement in the quality of sleep and life of the patients as well as their partners. The assessment of daytime sleepiness using the Epworth scale also improved 3 months after the end of treatment (Table 1, Fig. 5).

None of our patients reported a decreased quality of sleep or life. None of the patients reported postoperative complications or adverse effects of the Er:YAG laser treatment, such as postoperative bleeding, palatopharyngeal incompetence, regurgitation, infection of the mucous membrane of the oral cavity and the oropharynx, dysgeusia, or pain. None of the patients reported pain immediately after the procedure or later. After the treatment, 4 patients observed reduced gag reflexes, which had previously significantly impaired the activity of brushing teeth.

Discussion

Sleep has an enormous impact on normal human functioning. Snoring is one of the most common reasons for sleep disorders [26]. Treatment of snoring dates back to the mid-twentieth century [13]. Non-invasive methods (body-weight reduction, sleep position, alcohol/tobacco avoidance, positive airway pressure, dental appliances, medications) are of limited use and their efficacy is disputable. Surgical procedure is the only approach that can significantly reduce/eliminate snoring. New methods of surgical treatment have appeared over the last 70 years. They were initially characterized by significant invasiveness (UPPP), a relatively high risk of complications, and importantly, severe postoperative pain [13, 14]. Both patients and surgeons have searched for new, less invasive, and comparatively effective surgical treatment methods. In 1990, laser-assisted uvulopalatoplasty (LAUP) was introduced, and the development of intrapalatal techniques (radiosurgery, Pillar procedure, injection snoreplasty) was noted the end of the twentieth century. The extent of invasiveness and damage to the mucous membrane of the oropharynx is much lower in

Table 1 Results of the Wilcoxon Signed Rank Test ($\alpha = 0.05$) of baseline and post-treatment values of objective (polygraph measurements) and subjective (questionnaire) outcome measures. *p* values still considered significant after step-wise Bonferroni correction printed in italics. $n = 24$

Variable	Baseline		After tx		Median change	95% CI		*p*
	Median	Range	Median	Range		Lower	Upper	
Polygraph measurements								
OAI (no./h)	7.8	0.8–34	4.3	0.1–22	− 0.9	− 3.4	0.5	0.238
Hypopnea (no./h)	5.6	0.4–28	3.3	0.0–20	− 2.9	− 5.5	0.2	0.034
AHI (no./h)	19.0	2.5–72	11.6	2.8–48	− 3.1	− 8.1	0.7	0.085
Medium O_2 saturation (%)[b]	92.7 ± 1.6		92.9 ± 1.9		0.0	0.0	1.0	0.235
ODI (no./h)	12.3	1.3–60	9.5	0.6–56	− 0.8	− 6.5	0.5	0.232
Medium time of snoring episode (s)	17.0	5.7–39	13.0	4.8–155	− 1.0	− 5.8	2.4	0.579
Snoring (% of sleep time)	12.6	1.7–52	4.8	0.1–73	− 2.4	− 5.6	1.9	0.469
Questionnaires[a]								
Comfort of patient sleep (0–10 VAS)	8	1–10	3	1–9	− 3.5	− 4.0	− 3.0	*< 0.001*
Comfort of partner sleep (0–10 VAS)	9	5–10	3.5	1–9	− 4.0	− 5.5	− 3.0	*< 0.001*
Quality of life (0–10 VAS)	7	1–10	2	1–9	− 4.0	− 4.0	− 2.0	*< 0.001*
Epworth scale (0–24 score)	7.5	0–23	5.5	1–18	− 1.0	− 3.0	0.0	0.010

[a] Lower values on the VAS scale and Epworth score indicate better sleep. *OAI*, Obstructive Apnea Index; *AHI*, Apnea-Hypopnea Index; *ODI*, Oxygen Desaturation Index. [b] Mean and standard deviation

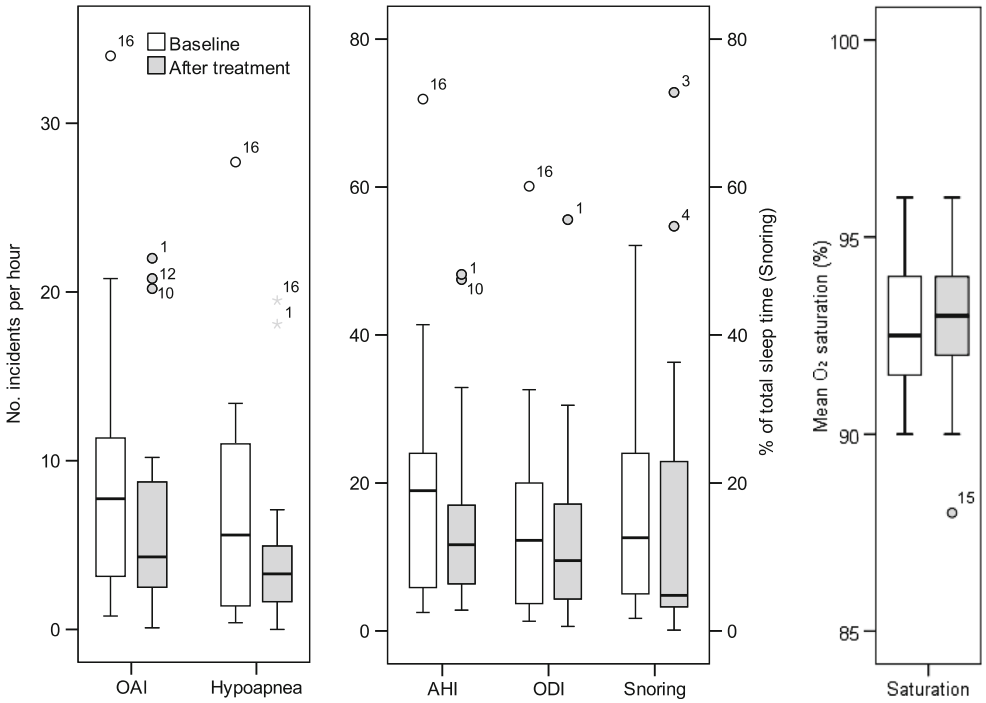

Fig. 4 Polygraphy results at baseline and 3 months after 3 laser treatments. The boxes indicate the 1st and 3rd quartiles, and the dark lines indicate the median. Whiskers contain the full range except for points more than 1.5 times the inter-quartile range away from the box, which are shown with circles. $N = 24$ for all variables

these procedures compared to LAUP or UPPP. However, local anesthesia is still required.

Postoperative pain intensity which is considerably lower, though still significantly causes fear in patients and reluctance to undergo treatment. Most surgical techniques used in the treatment of snoring are associated with pain and the possibility of recurrence in long-term follow-up [27, 28]. A new method of treatment using non-ablative Er:YAG laser does not

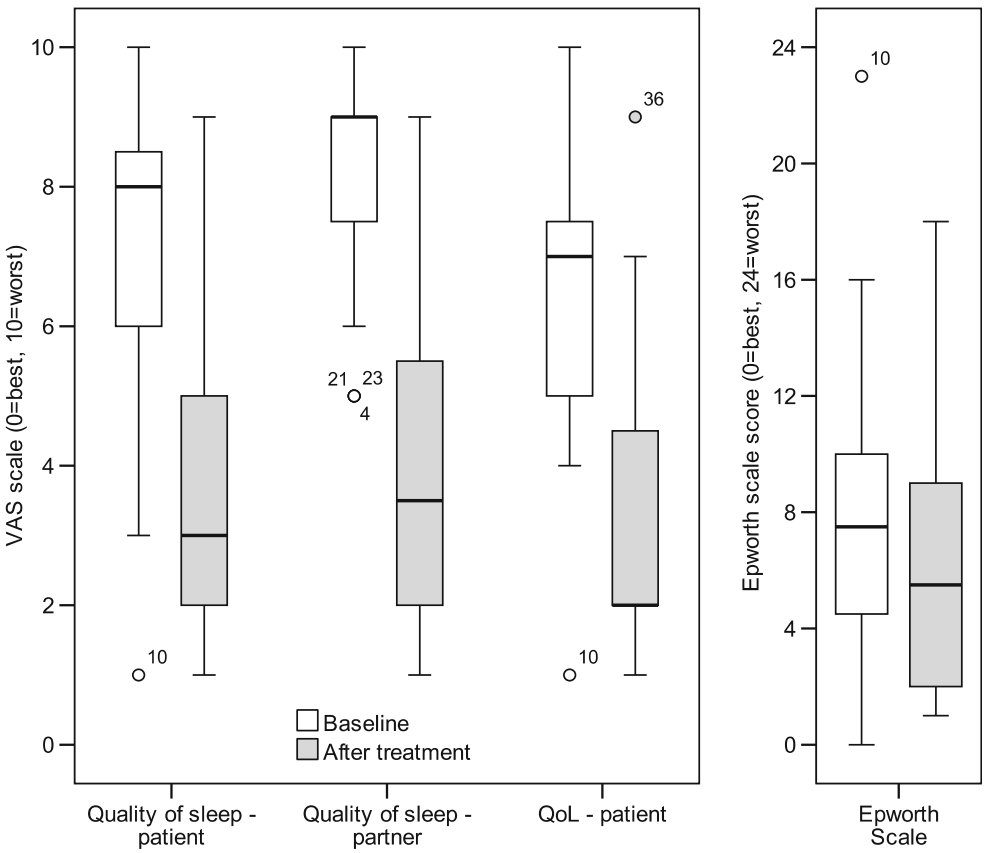

Fig. 5 Boxplot of subjective outcome measures before and 3 months after laser treatment for snoring. The boxes indicate the 1st and 3rd quartiles, and the dark lines indicate the median. Whiskers contain the full range except for points more than 1.5 times the inter-quartile range away from the box, which are shown with circles. All improvements had $p < 0.05$; however, the improvement in Epworth Sleepiness scale is not considered significant after step-wise Bonferroni correction for multiple comparisons. $N = 24$ for all variables

result in intra or postoperative pain. Dr. Jovanovic, who introduced this method, demonstrated treatment results of 21 patients and assessed reduction in snoring after the first session at, on average, 43% and after the second session at 62% [29]. The Er:YAG laser used in the present study emits infrared radiation with a wavelength of 2940 nm. Energy absorbed by the tissues of the oropharynx results in shrinkage of collagen fibers due to the photothermal effect and initiates neocollagenesis after 2–3 months [30, 31].

In our study, we analyzed a group of 24 patients who underwent Er:YAG laser snoring treatment in the oropharyngeal region. A statistically significant improvement was observed 3 months after treatment in all subjective outcome measures (questionnaires). While polygraph measurements also improved on average, this difference was only marginally significant for the number of hypopneas per hour. A larger study or one in which polygraph measurement was conducted for several nights [32], instead of a single night before and after treatment would have better power to detect improvement in polygraph variables.

Dovsak et al. conducted a study on 11 patients with AHI < 15. They reported that the average reduction of snoring duration was 11%. The treatment procedure in their study was consistent with the one used in our study [33]. Svahnström et al. conducted a study on 75 patients treated with the Er:YAG laser. Ninety percent of their patients reported full satisfaction after the treatment and an overall better quality of life (improved concentration, higher alertness and focus, reduced daytime sleepiness). Unfortunately, polysomnography was not performed by Svahnström et al. [4]. In the study of Miracki and Vizintin, a group of 57 snoring patients was analyzed. A positive response to treatment was observed in 75% of patients and 95.2% noted improvement in their snoring. As opposed to other studies, those patients reported pain. The average pain was 1.6 points after the first session and 1.4 points after the last session as assessed on the 0–5 scale. Finally, at the end of the study, those patients assessed the severity of pain as mild [34]. Cetinkaya et al. obtained a 65% satisfaction rate in 33 patients after three laser sessions as indicated by the questionnaire. The best results were obtained in the group of patients above 50 years of age [21]. Storchi et al. analyzed a group of 40 patients treated for snoring with the Er:YAG laser. Twenty-two patients presented with OSA syndrome. Postoperative polysomnography was done only in 11 patients. Subjective methods for the assessment of satisfaction were used. Eighty-five percent of patients were very satisfied, 12.5% reported fair satisfaction, and 1 patient (2.5%) was not satisfied. Contrary to our observations and the data from other authors, 4 patients (10%) required local lidocaine spray due to high gag reflexes [22].

Based on our observations, the treatment of snoring with the Er:YAG laser is an effective and non-invasive therapeutic method. Our hypothesis that non-ablative Er:YAG laser treatment is tolerable without anesthesia, is without serious complications, and provides significant improvement in both subjective and objective outcome measures was confirmed. Invasive surgical methods (UPPP, LAUP, RAUP, Pillar procedure) offer comparable effects; however, they are associated with significant postoperative pain [35]. To date, there have been no studies that compare the effectiveness of the treatment of snoring using the Er:YAG laser with other traditional methods. Further studies with long-term follow-up are warranted to assess the results of the treatment of snoring with the Er:YAG laser.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards. The study was approved by the Bioethical Committee at the Silesian Medical Chamber in Katowice, Poland (25/2016 of 27 July 2016).

Informed consent Informed consent was obtained from all individual participants included in the study.

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