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RHINOLOGY

Diode laser treatment of hypertrophic inferior turbinates and evaluation of the results with acoustic rhinometry

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Abstract Inferior turbinate hypertrophy is the most common cause of chronic nasal obstruction. When conservative medical treatment options fail in patients with inferior turbinate hypertrophy, reduction of the inferior turbinate can be performed using surgical techniques. Laser-assisted turbinate surgery has the advantages of limited tissue trauma and reduced bleeding. We evaluated the effectiveness and outcomes of using a diode laser ($\lambda = 980$ nm) in turbinate reduction. Our study included 62 patients with symptoms of nasal obstruction due to hypertrophic inferior turbinates, who did not respond to medical treatment ($\geq$1 year). Patients were treated with diode laser between January 2009 and December 2010 in our ENT (ear, nose, and throat) department. Subjective outcome of severity of nasal obstruction was assessed on a standard 10-cm visual analog scale (VAS). Acoustic rhinometry was used to measure nasal patency. The cross-sectional areas 1, 2, and 3 and the volumes between 2.5 and 5.5 cm were measured. VAS scores and acoustic rhinometry measurements were performed preoperatively and 1, 6, and 12 months after surgery. The mean follow-up was 13.1 $\pm$ 1 months. The mean operation time was 3 min per turbinate; no nasal packing was necessary. We did not observe any major complications. Both subjective and objective evaluations showed significant improvement. VAS scores improved, the mean MCA2, MCA3, and V2–5 measurements increased significantly 1 year after surgery. In the first year after surgery, 53 of 62 (85.4%) patients reported marked improvements in nasal breathing. Our results showed that, objectively and subjectively, the success rates in diode laser-assisted turbinate reduction were satisfactory. The diode laser, being one of the most portable and least expensive of the lasers available for turbinate surgery, makes it possible for turbinate reduction to be performed under topical anesthesia within a short period of time with excellent patient acceptance.

Keywords Nasal obstruction · Turbinate hypertrophy · Turbinate reduction · Diode laser · Acoustic rhinometry

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Introduction

Inferior turbinate hypertrophy (ITH) is the most common cause of chronic nasal obstruction. It is often associated with allergic rhinitis, vasomotor rhinitis, chronic hypertrophic rhinitis, and a compensatory response of septal deformity. When conservative medical treatment options, such as anti-histamines, topical decongestants, and topical corticosteroids, fail in ITH, reduction of the inferior turbinate can be performed using various surgical techniques. These include turbinectomy, turbinoplasty, extramucosal or submucosal electrocautery, radiofrequency ablation (RFA), microdebrider-assisted turbinoplasty (MAT), laser-assisted resection or ablation, and cryosurgery. The expected outcomes of turbinate surgery are maximal volumetric reduction of the inferior turbinate and lasting nasal patency. Although these methods may provide better results than medical treatment alone, occasionally some unpleasant effects, such as bleeding, uncontrolled damage to the mucosa, crust formation on the turbinates, postoperative pain, synechia, or atrophy of the inferior turbinate, may result. In addition, the improvement may not always persist over time.

Research is continuing to identify the most appropriate surgical treatment method for ITH that is less traumatic and provides long-lasting effective volume reduction. Laser surgery has the advantages of limited tissue trauma and reduced bleeding. Different lasers, such as carbon dioxide (CO_2), neodymium:yttrium–aluminum garnet (Nd:YAG), holmium:yttrium–aluminum garnet (Ho:YAG), potassium titanyl phosphate (KTP), diode, and argon plasma lasers, have been used to treat ITH [1, 2]. Laser-assisted turbinate surgery causes limited submucosal scarring and obliteration of the venous sinusoids, shrinking the turbinate and relieving nasal obstruction. The diode laser is the most portable and least expensive of the lasers available for rhinologic applications today [3–7]. The coagulating ability of the diode laser is more controllable than other lasers in the deep layer of the turbinate. Diode laser light ($\lambda = 980$ nm) is absorbed primarily by water and blood and has excellent coagulating abilities. The coagulating capability of non-contact type of lasers is not as deep as that of other lasers, such as Nd:YAG or KTP [2]. They use an optical fiber of 400–600 μm, and can ablate soft tissues without causing excessive collateral damage, which may help to avoid complications, especially in areas adjacent to the orbit.

Objective assessment of nasal cavity patency is important for determining the severity of nasal obstruction. There are a few objective techniques for assessing nasal obstruction, such as rhinomanometry, acoustic rhinometry, mucociliary transport time, magnetic resonance imaging, and computed tomography scans. Acoustic rhinometry is a noninvasive, painless, easily applicable method that provides objective documentation of rhinologic disorders [8–10]. Along with a careful clinical examination, it can provide objective documentation of ITH. Nasal patency can be measured and a map of the nasal cavity can be created before and after the surgery [7].

A few studies include objective data about turbinate reduction with a diode laser ($\lambda = 980$ nm). The present study evaluated the effectiveness and long-term outcomes of diode laser surgery in patients with ITH.

Materials and methods

All patients admitted with symptoms of nasal obstruction due to ITH were accepted as candidates. After documenting medical history and performing routine physical ear–nose–throat (ENT) examinations, each patient underwent endoscopic nasal evaluation. Computed tomography scans were obtained to investigate the bony structures of the nose. In particular, the bony part of the turbinates was assessed. Patients with nasal polyps, severe deviation of the septum, sinus infection, and nasal valve pathology were excluded. Previous nasal surgery and any systemic disorder, such as diabetes, were also exclusion criteria. As we sought to study chronic non-allergic rhinitis, to rule out allergic rhinitis, skin prick tests were performed and specific IgE levels were assessed in all patients. Nasal cavities were decongested for 5 min with cotton pledgets soaked in adrenaline at a concentration of 1/100,000. Only patients with evident shrinking of their inferior turbinates were included. Patients who had bony hypertrophy were excluded. Marked decongestion of the turbinates was accepted as indicative of soft tissue problem. Five cases that did not markedly show decongestion were accepted as bony hypertrophy. When we analyzed their paranasal CT sections, the mean anterior portion of inferior turbinate bone width was 3, 4 mm and the mean anterior portion of inferior turbinate width was 8.7 mm in those cases. So these cases were excluded from our study. These five patients were treated with microdebrider for turbinate hypertrophy. In total, 62 non-allergic cases who had ITH and who had not responded to medical intranasal steroid treatment ($\geq$1 year) prescribed in our ENT department were enrolled in this study. Bilateral diode laser turbinate surgery was performed between January 2009 and December 2010 in all members of the study group.

This study was approved by the university ethics committee (OGU2010/106). All patients were informed about laser-assisted turbinate surgery and informed consent was obtained in each case. The tenets of the Declaration of Helsinki were followed.

Subjective outcomes of the severity of nasal obstruction were assessed on a standard 10-cm visual analog scale (VAS), ranging from 0 (no episode of nasal obstruction) to 10 (indicating severe and unremitting nasal obstruction). All patients were asked for subjective ratings using the VAS before, 1 and 6 months and 1 year after laser treatment.

As an objective test, we used acoustic rhinometry (SRE 2,000, RhinoMetrics, Lynge, Denmark) to evaluate the nasal cavity. Three curves were acquired from each cavity. The examination was performed at room temperature (25°C), and the relative humidity was about 50%. All subjects remained seated for at least 20 min to acclimatize to the examination environment before testing. The following cross-sectional areas were determined: at 0.4 cm (CSA1), representing the nasal valve; at 2.2 cm (CSA2), representing the anterior part of the inferior turbinate; and at 5.5 cm (CSA3), representing the posterior part of the inferior turbinate. The V2–5 nasal cavity volume between the CSA3 and CSA2 sectional areas was measured and considered for each side of the nasal cavity volume. VAS scores and acoustic rhinometry measurements were determined and evaluated for each patient preoperatively and 1, 6, and 12 months after surgery. The mean follow-up was 13.1 $\pm$ 1 months. Pre- and postoperative data were compared.

The settings for the $\lambda = 980$ nm diode laser (Multidiode S30; Intermedic Arfran SA, Spain) were as follows: output power of 11 W in continuous-wave mode, laser delivery by a 600-μm semi-rigid quartz fiber using "contact" mode, and a total of 100-J energy applied to each inferior turbinate. The duration of diode laser application and total energy delivered were recorded.

Patients were requested to not use any nasal treatment in the 10 days prior to the operation. Diode laser treatment was performed by the same surgeon (HC). The ablation procedure was performed under topical anesthesia. Cotton pledgets soaked in 10% xylocaine and 0.05% oxymetazoline HCl were applied in both nasal passages for 10 min to achieve vasoconstriction and topical anesthesia. Throughout the procedure for the localization and documentation of the treatment, a rigid nasal endoscope (0° optic, OD 4 mm; Karl Storz, Tuttlingen, FRG) connected to a video device was used. After one shot to the mucosa of the anterior inferior turbinate, the diode laser probe of 600 μm was inserted into the anterior inferior turbinate and progressed parallel to the long axis to the posterior inferior turbinate. Then, three or four laser light applications were performed by drawing the fiber from the posterior to the anterior part of the inferior turbinate. Postoperatively, no nasal packing was applied and the nasal cavity was filled with antibiotic ointment. Patients were told to rinse their nose with saline solution three times per day for 3 weeks. They were not prescribed any other treatment.

Statistical evaluation of the results was performed using the SPSS software (ver. 15.0 for Windows; SPSS Inc, Chicago, IL). Two-way ANOVA with Tukey's HSD multiple comparison test was used to compare MCA2, MCA3, V5–V2, and VAS measurements according to preop and postop times. MCA2, MCA3, and V5–V2 measurement distributions were tested using the Kolmogorov–Smirnov normality test. A p value less than 0.05 was considered to indicate statistical significance.

Results

The study included 62 patients (29 females, 33 males), with a mean age of 41.61 ± 8.4 (range 25–58) years. The mean operation time for diode laser turbinate ablation was 3 min per turbinate (range 2–4 min/turbinate). Acute complications, such as major bleeding, were not observed; minor bleeding was observed in 4 of 62 (6.5%) patients but did not require nasal packing. It was controlled by placing cotton pledgets soaked in 0.05% oxymetazoline HCl in the nasal passage for 10 min. Nasal synechia between the nasal septum and the surface of the inferior turbinate was not observed in any patient. No patient suffered pain during or after the surgery. For all patients, an analgesic (paracetamol) was administered only on the first day after surgery. None complained of pain in the following days.

Diode laser use was tolerated by all of these patients with ITH. The only major complaint reported was the worsening of nasal obstruction during the first postoperative week, which can be explained by the likely development of reactive edema following the laser ablation. This situation continued on average for 10 days and gradually resolved within 2 weeks in all patients. The inferior turbinates were found to be swollen by anterior rhinoscopy and nasal endoscopy on the first day after laser application in all patients. This improved in 7 days in 49 of 62 (79%) patients; in the others, 8 of 13 (13%) patients improved in 10 days and 5 (8%) improved in 2 weeks. Crust formation on the turbinates was observed in only 2 of the 62 (0.3%) patients and improved within 10 days without sequelae. The operation parameters and minor complications are listed in Table 1.

Subjective assessments of the severity of nasal obstruction (VAS values) decreased significantly 1 and 6 months, and 1 year after the operation. Symptomatic improvement reached a maximum of 6 months after diode laser turbinate reduction. The mean symptom scores reported 1, 6, and 12 months after the surgery were 2.56 ± 1.03, 2.29 ± 0.71, and 2.82 ± 0.82, respectively, statistically significantly better than the preoperative values ($p < 0.001$). The preop and postop mean VAS scores for nasal obstruction and statistical results are shown in Table 2.

Table 1 Diode laser surgery parameters and surgery-related side effects

Mean operation time	3 min/turbinate	2–4 min
Mean energy applied per turbinate (J)	104	100–110 J
Minor bleeding	4 ($n = 63$)	0.6%
Nasal discharge	–	
Nasal dryness	3 ($n = 63$)	0.4%
Nasal crust	2 ($n = 63$)	0.3%
Pain	–	
Granulation tissue	–	

Table 2 Pre- and postop mean VAS scores for nasal obstruction

	Mean VAS scores		p
	M	SD	
Before surgery	8.88	0.57	
Postop 1st month	2.56	1.03	<0.001
Postop 6th month	2.29	0.71	<0.001
Postop 1 year	2.82	0.82	<0.001

M Mean visual analog scale scores, *SD* standard deviations for nasal obstruction

Table 3 Comparison of acoustic rhinometry values before and after the surgery

Before surgery		After surgery		
		Postop 1st month	Postop 6th month	Postop 1 year
MCA1(cm^2)				
Right	0.39 ± 0.15	0.38 ± 0.03	0.39 ± 0.01	0.38 ± 0.09
Left	0.37 ± 0.29	0.38 ± 0.04	0.37 ± 0.05	0.37 ± 0.02
Mean	0.38 ± 0.01	0.38 ± 0.05	0.37 ± 0.35	0.38 ± 0.02
	ns	ns	ns	ns
MCA2 (cm^2)				
Right	0.19 ± 0.05	0.30 ± 0.06	0.30 ± 0.05	0.29 ± 0.04
Left	0.19 ± 0.01	0.27 ± 0.06	0.28 ± 0.05	0.27 ± 0.04
Mean	0.19 ± 0.03	0.29 ± 0.05	0.29 ± 0.05	0.28 ± 0.03
		$p < 0.001$	$p < 0.001$	$p < 0.001$
MCA2 (cm^2)				
Right	0.19 ± 0.05	0.30 ± 0.06	0.30 ± 0.05	0.29 ± 0.04
Left	0.19 ± 0.01	0.27 ± 0.06	0.28 ± 0.05	0.27 ± 0.04
Mean	0.19 ± 0.03	0.29 ± 0.05	0.29 ± 0.05	0.28 ± 0.03
		$p < 0.001$	$p < 0.001$	$p < 0.001$
MCA3 (cm^2)				
Right	0.22 ± 0.04	0.19 ± 0.04	0.26 ± 0.05	0.25 ± 0.03
Left	0.23 ± 0.02	0.26 ± 0.04	0.27 ± 0.05	0.26 ± 0.02
Mean	0.23 ± 0.03	0.27 ± 0.05	0.26 ± 0.05	0.26 ± 0.03
		$p < 0.001$	$p < 0.001$	$p < 0.001$
V2–5 (cm^3)				
Right	2.96 ± 0.67	4.99 ± 0.94	4.91 ± 0.94	4.71 ± 0.80
Left	3.07 ± 0.05	4.72 ± 0.81	4.63 ± 0.81	4.46 ± 0.63
Mean	3.01 ± 0.05	4.86 ± 0.71	4.50 ± 0.71	4.31 ± 0.96
		$p < 0.001$	$p < 0.001$	$p < 0.001$

Patient satisfaction rates (patients with VAS scores ≥ 4) 1, 6, and 12 months after surgery were 88.7% ($n = 55$), 90.3% ($n = 56$), and 85.4% ($n = 53$), respectively. One year after surgery, 53 of 62 patients (85.4%) reported marked improvement in nasal breathing, which was confirmed by the acoustic rhinometric data. Nine patients reported dissatisfaction with nasal breathing. When we controlled the objective and subjective data, the VAS scores and acoustic rhinometry measurements were actually normal in three of these nine patients; also, their inferior turbinates had shrunk and nasal patency was adequate by endoscopic examination. When we re-examined the findings, we noticed that they had high septal deviations that did not obstruct the nasal passage in the paranasal CT scans.

The mean CSA1 values did not differ before and after surgery, whereas the mean CSA2, CSA3, and V2–5 values significantly increased (two-way ANOVA with Tukey's HSD; $p < 0.001$) after laser treatment compared to the preoperative values. The acoustic rhinometry values before and after surgery are listed in Table 3.

Discussion

Hypertrophy of the inferior turbinate is one of the most frequent causes of nasal obstruction and, generally, is a result of sinonasal pathology. When medical therapy fails, there are several surgical procedures, including partial and total turbinectomy, turbinoplasty, extramucosal or submucosal electrocautery, RFA, MAT, laser-assisted ablation or resection, and cryosurgery [1, 11]. Studies that have reviewed these surgical techniques for reducing ITH have generally concluded that MAT, RFA, and laser-assisted ablation are mucosal-sparing techniques and that the preferred approach should be infra-turbinal turbinoplasty [1, 11]. These are the most studied techniques that have been used recently for ITH [1, 11]. However, it must be emphasized that more studies with objective data and long-term follow-up are needed [1, 11]. We have performed using MAT, RFA [12], and diode laser-assisted endoscopic dacryocystorhinostomy (DCR) surgery to treat ITH, and have observed that the diode laser has advantages such as shorter recovery period and operating time, and reduced

morbidity and side effects, such as bleeding, development of synechia, and granulation of the nasal mucosa [13]. Few studies have reported the use of the diode laser for ITH. Based on our knowledge and experience, we sought to evaluate the use of the diode laser for ITH using subjective and objective data.

Treatment of nasal obstruction should be rationally based on an assessment of the type and degree of obstruction. Objective documentation of the type and degree of obstruction can aid in making accurate diagnosis and evaluating postoperative success. Both rhinomanometry and acoustic rhinometry have been used to quantify nasal obstruction objectively. Rhinomanometry provides objective documentation of the obstruction of airflow, but does not indicate the location where the obstruction might be; it can only demonstrate the functional effect of a blockage [8]. In contrast, with acoustic rhinometry, the location and reversibility of each area of functional blockage and a topographic map of the nasal cavity can be determined with numerical quantification [9, 10]. Nasal patency or blockage is a subjective feeling, which is very hard to measure and compare quantitatively. To evaluate the efficacy of the treatment modality, we need subjective measurements. Although acoustic rhinometry has some limitations and disadvantages, such as being expensive and time-consuming, and difficulty in learning to use and interpret, it is still accepted as a standard in the evaluation of nasal patency [9, 10]. Considerable improvements have been made in acoustic rhinometry in the recent years. New models are cheaper and user friendly. There is discussion about the accuracy of acoustic rhinometric measurements greater than a distance of 6 cm from the nostril. For this reason, 5.5 cm was used as the cutoff value for the volumetric calculation in our study.

Lasers that have been used to treat hyperplastic inferior turbinates include Nd:YAG (neodymium:yttrium–aluminum garnet), Ho:YAG (holmium:yttrium–aluminum garnet), argon, CO_2 (carbon dioxide), KTP (potassium titanyl phosphate), and diode lasers [1, 2, 11]. KTP and argon laser light are absorbed by endogenous chromophores, such as hemoglobin and melanin, and the coagulation depth is up to 2 mm. CO_2 laser light is highly absorbed by water, causing surface tissue ablation [2]. The Ho:YAG laser delivers high pulsed energy. The wavelength, 2,100 μm, is strongly absorbed by water, and the depth of the coagulation zone is shallow. It is an effective but expensive system [2]. The Nd:YAG laser is poorly absorbed by most chromophores and, therefore, exhibits a high degree of scatter. The depth of penetration and thermal damage can be of several millimeters, leading to potentially gross tissue loss [1, 2, 11]. The diode laser technology is the newest addition to the list for nasal applications. Diode laser equipment is relatively cheap and extremely portable [3–7]. There are various diode laser models that emit at different frequencies, ranging from $\lambda = 805$ to $\lambda = 980$ nm. The $\lambda = 805$ nm beam is strongly absorbed by hemoglobin. Light at $\lambda = 940$ and 980 nm are also absorbed by water [2–7]. With the exception of the CO_2 laser, the other lasers mentioned can be delivered using a flexible quartz fiber in contact or non-contact mode.

Sroka et al. [7] compared Ho:YAG and diode lasers ($\lambda = 940$ nm) for turbinate reduction. Both techniques resulted in statistically significant improvement in nasal airflow at 3 years postoperatively; subjective improvement was 67.5% for the Ho:YAG laser and 74.4% for the diode laser. Of the patients suffering from nasal obstruction, 46% had allergic rhinitis. They observed that side effects of the diode laser were fewer than those with the Ho:YAG laser in their study. They evaluated their results using rhinomanometry and found a significant improvement. They reported that these minimally invasive techniques had similar results, were cost-effective, and could be used with very short operation times. Janda et al. [3] used a diode laser ($\lambda = 940$ nm) in 76 patients (52% suffering from allergic rhinitis); 86% of the patients described subjective improvement in nasal airflow at 6 months and 76% of the patients did so 1 year after laser treatment. Patient evaluations by rhinomanometry showed worsening in 2.5%, no significant change in 34%, and improvement of nasal airflow in 63.5%. The study did not include detailed results of the acoustic rhinometry measurements, but reported an increase in 11.4% of the patients' mean nasal cavity volume (V3.3-6.4) 6 months after laser treatment and an increase of 7.6% compared to the preoperative volume 1 year after laser treatment. Acoustic rhinometry has been used for anatomical evaluations of nasal cavity dimensions; it provides static and anatomical evaluations of the nasal cavity, whereas rhinomanometry is a dynamic and physiological assessment. In this study, we found that the values of minimum CSA2, CSA3, and V2–5, measured by acoustic rhinometry, were correlated in terms of nasal stuffiness and acoustic rhinometric assessment. CSA1 represents the nasal valve and similar pre- and postoperative CSA1 values are the expected results of turbinoplasty. We believe that the calculation of the nasal volume is important in patients with ITH. We assessed the volume of the nasal cavity between the CSA3 and CSA2 sectional areas (in cm^3; V2–5) and found a correlation between V2–5 values and subjective nasal patency perception. The accuracy of acoustic rhinometric measurements diminishes after a distance of 6 cm from the nostril; this is important in obtaining reliable results. Thus, 5.5 cm was used as the cutoff value for the volumetric calculation in our study.

Volk et al. [6] investigated the effects of a diode laser ($\lambda = 980$ nm) for turbinate reduction in 41 patients and evaluated using rhinomanometry before and 8 weeks after

the operation. They reported that the nasal flow was 78% higher and that the improved rate, as expressed by the patients, was 73%. They did not observe any severe complications and reported a lack of correlation between subjective improvement with rhinomanometry measurements, suggesting that it could be due to the nature of flow in the nose and the sensitivity of the mucosa. We agree with this opinion; we observed that nasal patency was sufficient by endoscopic examination and that acoustic rhinometric measurements were improved, but subjective complaints of obstruction did not change in 3 of the 62 patients 1 year after surgery. We noticed that they had high-situated deviations and considered that this could influence the sensitivity of the nasal mucosa. Volk et al. [6]. proposed that performing rhinomanometry with topical decongestion and calculating the volume before the surgery could help in estimating the benefit from laser surgery. Performing topical decongestion in the nasal cavity and seeing the shrinking of the turbinates before deciding on the appropriate procedure for a patient have been used by many authors. We also used this method and included CT scans in the evaluation. Patients who have bony hypertrophy in the turbinates are not suitable for laser surgery.

Caffier et al. [5] used a diode laser ($\lambda = 830$ nm) for inferior turbinate reduction in 42 patients with rhinitis medicamentosa and evaluated the results with rhinomanometry 6 months and 1 year after surgery. They reported rates of improvement of 88 and 74%, respectively. They did not encounter major complications, but only postoperative turbinate edema, which disappeared within the first week, and a crust, which improved within 6 weeks.

Our patient satisfaction rates (patients with VAS scores $\geq$4) 1, 6, and 12 months after surgery were 88.7, 90.3, and 85.4%, respectively. One year after surgery, 53 of 62 (85.4%) patients reported marked improvement in nasal breathing, which was confirmed by acoustic rhinometric data. Our patient satisfaction rates are consistent with the results of other studies that have used diode lasers for turbinate reduction [3–7]. Our success rate at 12 months after surgery was better than those from other reports. This could be related to our patient selection. We excluded patients with allergic rhinitis. We thought that other symptoms of allergic rhinitis could affect evaluations of nasal patency. Another reason for our success could have been related to the diode laser ($\lambda = 980$ nm) used in the surgery. The side effects we observed included minimal bleeding, which did not require nasal packing, and nasal swelling that improved in 1 week. Our side effect rate was >1% and better than other reports with diode lasers [3–7]. This too may be related to the lack of patients with allergic rhinitis in our study.

If we consider the results of other laser techniques that have been used for turbinate surgery, Lippert and Werner [14] used a CO_2 laser and reported an improvement in nasal breathing of 82% 1 year after surgery. Kawamura et al. [15] reported a success rate of 85% 2 years after CO_2 laser turbinate surgery. Fukutake et al. [16] also used a CO_2 laser and reported that 77% of the patients had subjective improvement 1 year after surgery. Levine et al. [17] reported that there was an improvement with KTP laser turbinectomy in 80% of the patients. Olthoff [18] used an Nd:YAG laser for the treatment of allergic and vasomotor rhinitis and reported a success rate of 80% after turbinoplasty. Lippert and Werner reported [19] an improvement in 72.5% of patients using an Nd:YAG laser for turbinate reduction 1 year after surgery. Leuning et al. [20] found subjective improvement in nasal obstruction in 77% of patients 1 year surgery, and Serrano et al. [21] reported improvement in 52.2% of patients 16 months after surgery with an Ho:YAG laser. A success rate of 71–80% was reported 1 year after argon laser turbinate surgery [2]. Thus, for all of these techniques, success rates varied between about 50% and about 80%. Side effect rates were reported as 5–10% and the mean application times were reported as 10–20 min [14–21].

Other mucosal-sparing techniques include MAT and RFA. Probably the most common currently used technique for turbinoplasty is RFA [1, 11]. Both methods successfully improve nasal airway patency. Success rates of 70–85% have been reported for RFA and of 80% have been reported for MAT in patients with ITH 1 year after surgery [1, 11, 22–26]. We have found that diode laser turbinate reduction results are better than these methods. Operation times have been reported to be 10–15 min for RFA and 10–20 min for microdebrider-assisted surgeries; 20–50% of patients have mucosal tears immediately following these procedures and synechiae are seen in 5% of patients.

Minor side effects have been reported to be more common in RFA than in MAT. The most common complaint is pain during and after surgery and this is observed more often with RFA. Postoperative bleeding requiring operative intervention is noted in 1–2% of patients [1, 11, 22–26]. The high cost of microdebrider blades and bipolar turbinate probes are disadvantages of these techniques.

We believe that the mucosal-sparing techniques of turbinate surgeries will be used more in the future than other techniques. Patients should be assessed individually to select the surgical technique that may provide the best result. There is no consensus yet about how to evaluate the success of turbinate surgery in the follow-up period. Acoustic rhinometric measurements provide objective data with numerical quantifications pre- and postoperatively in patients with ITH. Our results showed that, objectively and subjectively, the success rates of diode laser ($\lambda = 980$ nm)-assisted turbinate surgery were satisfactory. The diode laser, being one of the most portable and least

expensive of the lasers available for turbinate reduction, allows the procedure to be performed painlessly under topical anesthesia in a short period of time with excellent patient acceptance.

References

1. Chang CW, David Ries W (2004) Russell surgical treatment of the inferior turbinate: new techniques. Curr Opin Otolaryngol Head Neck Surg 12(1):53–57
2. Hüttenbrink KB (2005) Current topics in otolaryngology—head and neck surgery lasers in otorhinolaryngology. In: Lippert BM (ed) Lasers in rhinology. Thieme, New York, pp 53–71
3. Janda P, Sroka R, Tauber S, Baumgartner R, Grevers G, Leunig A (2000) Diode laser treatment of hyperplastic inferior nasal turbinates. Lasers Surg Med 27:129–139
4. Janda P, Sroka R, Baumgartner R, Grevers G, Leunig A (2001) Laser treatment of hyperplastic inferior nasal turbinates: a review. Lasers Surg Med 28(5):404–413
5. Caffier PP, Frieler K, Scherer H, Sedlmaier B, Goktas O (2008) Rhinitis medicamentosa: therapeutic effect of diode laser inferior turbinate reduction on nasal obstruction and decongestant abuse. Am J Rhinol 22:433–439
6. Volk GF, Pantel M, Lichius OG, Wittekindt C (2010) Prognostic value of anterior rhinomanometry in diode laser turbinoplasty. Arch Otolaryngol Head Neck Surg 136(10):1015–1019
7. Sroka R, Janda P, Killian T, Vaz F, Betz CS, Leunig A (2007) Comparison of long term results after Ho:YAG and diode laser treatment of hyperplastic ınferior nasal turbinates. Lasers Surg Med 39:324–331
8. Hilberg O, Jackson AC, Swift DL, Pedersen OF (1989) Acoustic rhinometry: evaluation of nasal cavity geometry by acoustic reflection. J Appl Physiol 66:295–303
9. Naito K, Miyata S, Saito S, Sakurai K, Takeuchi K (2001) Comparison of perceptional nasal obstruction with rhinomanometric and acoustic rhinometric assessment. Eur Arch Otorhinolaryngol 258(10):505–508
10. Corey JP (2006) Acoustic rhinometry: should we be using it? Curr Opin Otolaryngol Head Neck Surg 14(1):29–34
11. Bhandarkar ND, Smith TL (2010) Outcomes of surgery for inferior turbinate hypertrophy. Curr Opin Otolaryngol Head Neck Surgery 18:49–53
12. Cingi C, Ure B, Cakli H, Ozudogru E (2010) Microdebrider-assisted versus radiofrequency-assisted inferior turbinoplasty: a prospective study with objective and subjective outcome measures. Acta Otorhinolaryngol Ital 30:138–143
13. Basmak H, Cakli H, Sahin A, Gursoy H, Ozer A, Colak E (2011) What is the role of partial middle turbinectomy in endocanalicular laser-assisted endonasal dacryocystorhinostomy? Am J Rhinol Allergy 25(4):160–165
14. Lippert BM, Werner JA (1997) CO_2 laser surgery of hypertrophied inferior turbinates. Rhinology 35:33–36
15. Kawamura S, Fukutake T, Kubo N, Yamashita T, Kumazawa T(1993) Subjective results of laser surgery for allergic rhinitis. Acta Otolaryngol Suppl Stockh 109–112
16. Fukutake T, Yamashita T, Tomoda K, Kumazawa T (1986) Laser surgery for allergic rhinitis. Arch Otolaryngol Head Neck Surg 112:1280–1282
17. Levine HL (1989) Endoscopy and the KTP/532 laser for nasal sinus disease. Ann Otol Rhinol Laryngol 98:46–51
18. Olthoff A, Martin A, Liebmann F (1999) Nd:YAG laser treatment of hyperreflectory and allergic rhinopathy. Laryngorhinootologie 78:240–243
19. Lippert BM, Werner JA (1996) Nd:YAG laser light-induced reduction of nasal turbinates. Laryngorhinootologie 75:523–528
20. Leunig A, Janda P, Sroka R, Baumgartner R, Grevers G (1999) Holmium YAG laser treatment of hyperplastic inferior nasal turbinates. Laryngoscope 109:1690–1695
21. Serrano E, Percodani J, Yardeni E, Lombard L, Laffitte F, Pessey JJ (1998) Holmium YAG laser for treatment of inferior turbinate hypertrophy. Rhinology 36:77–80
22. Hytöonen ML, Bäck LJJ, Malmivaara AV, Roine RP (2009) Radiofrequency thermal ablation for patients with nasal symptoms: a systematic review of effectiveness and complications. Eur Arch Otorhinolaryngol 266:1257–1266
23. Coste A, Yona L, Blumen M et al (2001) Radiofrequency is a safe and effective treatment of turbinate hypertrophy. Laryngoscope 111:894–899
24. Lee JY, Lee JD (2006) Comparative study on the long-term effectiveness between coblation- and microdebrider-assisted partial turbinoplasty. Laryngoscope 116:729–734
25. Li KK, Powell NB, Riley RW, Troell RJ, Guilleminault C (1998) Radiofrequency volumetric tissue reduction for treatment of turbinate hypertrophy: a pilot study. Otolaryngol Head Neck Surg 119:569–573
26. Cavaliere M, Mottola G, Lemma M (2005) Comparison of the effectiveness and safety of radiofrequency turbinoplasty and traditional surgical technique in treatment of inferior turbinate hypertrophy. Otolaryngol Head Neck Surg 133:972–978