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Clinical feasibility trial on 1940 nm Tm: fiber laser intervention of hyperplastic inferior nasal turbinates

Klinische Machbarkeitsstudie zur Anwendung des 1940 nm Thulium-Faserlasers bei Nasenmuschel-Hyperplasie

Abstract

Introduction: A number of different laser systems have been used for volume reduction of hyperplastic nasal turbinates. In case of endonasal application, fiber-controlled diode lasers are preferred due to reasons of cost and practicability. The aim of this clinical feasibility study was to show the coagulative and tissue reducing effects using a novel Tm: fiber laser system emitting at $\lambda=1940$ nm.

Patients and methods: This clinical feasibility trial included 11 patients suffering from hyperplastic inferior nasal turbinates, who were therapy-refractory to conservative medical treatment. The obstructive nasal cavity was treated using the 1940 nm Tm: fiber laser at <5 W output power. The treatment was performed in non-contact mode under endoscopic control. Patients' symptoms were documented both preoperatively and on days 1–3 and 28 postoperatively using a non-validated questionnaire. Additionally, an endoscopic examination was performed.

Results: None of the patients showed infections, and no hemorrhages or other complications occurred intra- or postoperatively. The mean laser activation time during the surgical procedure was extremely short being 28.0 ± 8.5 s. In conjunction with a low power setting (median, 3 W; mean $\pm$ standard deviation, 3.3 ± 1.1 W), a low energy of 90.2 ± 37.8 J was applied. A significant reduction in nasal obstruction could be documented in all patients on day 28 postoperatively. Evaluation, as assessed preoperatively and 4 weeks postoperatively, showed significant subjective improvements.

Conclusion: The treatment of hyperplastic inferior turbinates using a 1940 nm Tm: fiber laser provides sufficient tissue reduction in a short operation time using low total energy. Patients described a significant improvement in nasal breathing postoperatively.

Keywords: Tm: fiber laser; ENT; hyperplastic turbinate; synechia.

Zusammenfassung

Einleitung: Zur Behandlung der symptomatischen Nasenmuschel-Hyperplasie wurden bislang unterschiedliche Laser klinisch eingesetzt. Bei endonasaler Applikation werden Lichtwellenleiter-assistierte Diodenlaser bevorzugt, sowohl wegen ihrer Kosteneffizienz als auch ihrer Praktikabilität. Im Rahmen der vorliegenden klinischen Machbarkeitsstudie wurden die koagulativen und ablativen Eigenschaften eines neuartigen 1940 nm Thulium-Faserlasers untersucht.

Patienten und Methodik: In die Machbarkeitsstudie wurden 11 bislang konservativ behandelte, aber therapierefraktäre Patienten mit Atembeschwerden aufgrund einer Nasenmuschel-Hyperplasie einbezogen und mit dem Thulium-Faserlaser behandelt. Die Lichtwellenleiter-gestützte Behandlung erfolgte unter Sichtkontrolle im Non-Kontakt-Verfahren mit weniger als 5 W Laserleistung. Die operativen Parameter wurden dokumentiert. Sowohl präoperativ als auch an den Tagen 1–3 und 28 nach der Operation wurde das Befinden der Patienten anhand eines Fragebogens evaluiert und eine endoskopische Nachuntersuchungen durchgeführt.

Ergebnisse: Sowohl während als auch nach der Behandlung zeigten die Patienten keine Anzeichen einer Infektion. Blutungen oder andere Komplikationen traten nicht auf. Die mittlere Expositionszeit betrug 28.0 ± 8.5 s. In Verbindung mit der geringen Laserleistung (Median: 3 W, Mittelwert: 3.3 ± 1.1 W) wurde so eine entsprechend geringe Lichtenergie von 90.2 ± 37.8 J appliziert. Am Tag 28 postoperativ wurde eine signifikante Reduktion des Nasenmuschelvolumens festgestellt. Die subjektive Wahrnehmung der Nasenatmung war signifikant verbessert.

Zusammenfassung: Die Anwendung des 1940 nm Thulium-Faserlasers zur minimal-invasiven Behandlung der Nasenmuschel-Hyperplasie resultierte in einer zufriedenstellenden Reduktion des Gewebenvolumens bei kurzen Behandlungszeiten und geringer applizierter

Gesamtenergie. Von Seiten der Patienten wurde eine signifikante Verbesserung der Nasenatmung berichtet.

Schlüsselwörter: Thulium-Faserlaser; HNO; Nasenmuschel-Hyperplasie; Synechie.

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1 Introduction

Inferior turbinate hypertrophy is a common cause of nasal airway obstruction. Patients that are refractory to conservative pharmacological treatment require surgery. Over the years, various surgical techniques have been applied including total or partial turbinectomy, submucous resection, laser surgery, electrocautery, cryosurgery, and radio-frequency ablation [1]. Endonasal laser treatments cause limited tissue trauma with little or no bleeding, and have a high patient acceptance [2–5]. Since the early 1980s, various types of laser systems have been used for surgical endonasal applications. Systems most frequently used are the carbon dioxide (CO₂), neodymium:yttrium-aluminum-garnet (Nd:YAG), holmium:yttrium-aluminum-garnet (Ho:YAG), and frequency-doubled Nd:YAG (KTP) laser, as well as diode lasers of different wavelengths [6, 7].

Due to the specific emitting wavelength, light-tissue interactions change with respect to the optical parameters of the tissue. Most of the commonly available laser systems for both outpatient treatment and clinical applications provide light at wavelengths of $\lambda=800\text{--}1000\text{ nm}$, mainly causing coagulative tissue effects when applied in non-contact mode. In comparison to CO₂ and Nd:YAG lasers, diode lasers have lower acquisition and maintenance costs, and are more versatile in the clinical setting due to their smaller size.

New technical devices such as the investigated 1940 nm thulium-doped fiber (Tm: fiber) laser – already CE

certified for medical use – offers good ablative as well as coagulative tissue effects due to its absorbance profile within human tissue. A wider range of laser applications may be achieved by this fiber-guided wavelength. The present prospective study was carried out to show the feasibility of clinical application of the 1940 nm Tm: fiber laser for laser-induced reduction of nasal hyperplastic turbinates. The qualitative laser light-tissue interaction was investigated and documented. During the follow-up examinations subjective sensation was determined by means of a non-validated questionnaire. Both the pre- and post-operative subjective sensation of the patients was compared. Furthermore, intraoperative handling and clinical appearance after treatment were subjectively documented by the surgeon.

2 Materials and methods

2.1 Patients and study design

The study was designed as a prospective, non-blinded and single center trial. Patients who suffered from bilateral inferior nasal turbinate hypertrophy – diagnosed either subjectively or by rhinomanometry – and who were therapy-refractory to conservative medical treatment, could be included in this feasibility trial after giving an informed consent. Ethical approval was obtained from the Ethical Committee of Ludwig-Maximilians-University of Munich. Exclusion criteria included the contraindication to laser surgical treatment under local anesthesia, acute and chronic sinusitis, nasal polyps (*polyposis nasi et sinuum*), massive septum deviation (*subluxatio septi*), allergic reaction to superficial anesthetics, pregnancy, and those aged under 18 years.

2.2 Clinical procedure

The complete treatment using a 1940 nm Tm: fiber laser (vela®, StarMedTec GmbH, Starnberg, Germany) was performed in a clinical setting under general anesthesia because additional surgical interventions were performed simultaneously during the same surgical session. Usually, the laser-assisted reduction of turbinate hypertrophy is carried out under local anesthesia [5–7].

Turbinate shrinkage was performed using Privine® embedding for 10–15 min. Documentation of both nasal cavities was performed prior to and during the operation as well as during the follow-up via a rigid endoscope

(0°/4 mm; Karl Storz, Tuttlingen, Germany) in combination with a video-documentation device (Image 1/AIDA system; Karl Storz, Tuttlingen, Germany). Laser light application was performed in non-contact mode using a flexible silica fiber (365 μm) guided via a device for precise endonasal fiber guidance (ENT-fiber guidance system; Karl Storz, Tuttlingen, Germany) [8]. Initially, the laser power was set to 1 W, and then increased stepwise within a range of 3–5 W in order to find the optimum setting.

For optimal positioning of the fiber the pilot beam ($\lambda=532\text{ nm}$) was adjusted to 30% continuous wave enabling an optimized aiming and guidance without reflection. Laser light application itself was performed by guiding the fiber from the posterior to the anterior free edge of the inferior turbinate under endoscopic control. Laser light was applied until adequate whitening of the tissue was obtained as judged by the operating surgeon. In cases where the head of the inferior turbinate seemed especially prominent, some single laser spots were directed solely onto the head of the turbinate.

Postoperatively, nasal cavities were treated with antibiotics and steroid-containing ointment (Jellin-Neomycin® containing 0.25 g fluocinolone acetonide and 4.25 g neomycin sulfate). Additionally, patients received prescriptions for nasal ointments and nasal decongestants.

2.3 Documentation

During treatment, handling and survey of treatment site (0=bad, 10=very good), coagulation response in terms of whitening sensation (1=bad, 2=moderate, 3=very good), and the occurrence of intraoperative bleeding (1=no, 2=minor, 3=need for intervention) were rated by the physician. Thus, a subjective comparison to the experiences using other lasers for laser-assisted reduction of hypertrophic nasal turbinate could be obtained. The time of laser surgery, laser power settings, and total amount of applied energy were documented after completion of the laser surgical procedure.

Prior to operation, 1–3 days post operation and after a follow-up period of 28 days, patients were asked to complete a questionnaire in order to evaluate and to compare their subjective perception. This questionnaire contained questions regarding the nasal breathing, nasal secretion, crust formation, and pain for each individual nostril. In addition, general occurrence of xerostomia, snoring, and nasality was queried. Answers were given as scores from 1=negative to 10=massive/frequent. Finally, patients were asked if they would have the procedure repeated and/or recommend it to a friend.

Video endoscopic documentation was performed prior to the operation and decongestion of the turbinate, during the operation, immediately after laser treatment, as well as on days 1–3 and 28 days after operation.

2.4 Evaluation and statistics

As the intra-operative rating was performed by one single physician, mean and standard deviations were derived from all documented values.

Questionnaires were evaluated by calculating median, mean and standard deviation. Furthermore, changes between pre-, post- and follow-up period were analyzed using the two-tailed Student's t-test for continuous data, normality-test and Wilcoxon-Rank-test (Sigma-Plot 11.0; Jandel Scientific, San Rafael, USA). A $p<0.05$ was considered as statistically significant.

Some examples of endonasal laser treatments are described.

3 Results

3.1 Procedure-related results

No complications related to the treatment were observed intra-operatively. After initial variation of the laser power between 1 and 5 W, the median laser power applied was set to 3 W (overall mean $\pm$ standard deviation: $3.3\pm1.1\text{ W}$). The mean laser light application time during the operation was $28.0\pm8.5\text{ s}$ (range: 10–40 s) resulting in a total applied energy of $90.2\pm37.8\text{ J}$ (range: 12–180 J). The coagulation capabilities of the laser were scored as very good and fast; no bleeding occurred during laser treatment. Handling of the laser device was easy and intuitive, fiber maneuvers using the fiber-guidance system were straight forward. The visibility of the treatment site was clear.

3.2 Patient questionnaire

There was a significant reduction of the subjective general nasal congestion as well as reduction of the nasal obstruction during physical exertion on day 28 postoperatively as compared to preoperative findings ($p<0.05$). Regarding xerostomia, snoring, and nasality, there was tendentious but not significant reduction ($p>0.05$) in symptom severity on day 28 postoperatively as compared to preoperative findings. Nasal breathing was significantly improved ($p<0.01$) in all patients during the follow-up

period (median score: 2, mean score: 1.6 ± 1.1) compared to the preoperative situation (median score: 5, mean score: 4.9 ± 2.3). Nasal pain sensation showed an overall reduction after initial wound healing time ($p > 0.05$). Nasal crust formation declined during follow-up significantly ($p < 0.01$). Nasal secretion was reduced after the follow-up period compared to the pre-operation situation ($p > 0.05$). No infection, bleeding or other complications were reported by the patients in the course of the postoperative period. All patients declared that the performed procedure is acceptable and that they would have it repeated it again; furthermore, they would recommend the procedure and the mode of anesthesia to a friend.

3.3 Clinical appearance

In Figures 1 and 2, examples of two patients receiving 1940 nm Tm: fiber laser-assisted treatment for reducing the volume of nasal hyperplastic turbinates are depicted showing both the right and the left nasal cavity, respectively. The comparison of Figure 1A and B and Figure 2A and B, respectively, documents the shrinkage of the turbinate due to Privine® embedding for about 10–15 min. Figures 1C and 2C show the whitish coagulation of the tissue immediately after laser treatment. After wound healing and follow-up periods of 28 days (Figure 1D) and 42 days (Figure 2D), the fresh re-epithelialized surface of the nasal turbinates can be seen. Comparison of the turbinate size and the free lumen of the nasal cavities in Figure 1A and D and Figure 2A and D, respectively, clearly demonstrates the 1940 nm laser-induced tissue reduction, which is furthermore free from scar formation.

4 Discussion

Diode laser systems have been reported as being useful tools for medical applications [9–11]. The current clinical trial shows the safety and efficiency of a 1940 nm Tm: fiber laser system for volume reduction of hyperplastic turbinates. The macroscopically visible tissue effect produced by the 1940 nm Tm: fiber laser was observed by the operating surgeon and judged according to tissue whitening which was equivalent to the effects of diode laser systems emitting 940 nm (laser power, 12 W; laser on, 3.3 min; applied energy, 700 J) and 1470 nm (laser power, 5 W; laser on, 2.5 min; applied energy, 150 J) [7]. But compared to these procedures, the Tm: fiber laser treatment required a significantly shorter treatment time of <1 min and reduced total energy amount of <100 J. The overall

time for endonasal laser treatment (without anesthesia and decongestion) was <5 min.

The overall pain sensation during a follow-up period of 28 days, as described by the patients, was low. Neither minor nor major complications (neither intra- nor postoperatively) were witnessed in the group of patients treated, which corresponds well with the published literature for diode laser coagulation of inferior nasal turbinates [12–14].

The main symptoms due to hyperplastic inferior turbinate (nasal congestion and nasal obstruction during exertion) were significantly improved according to the questionnaire used. This questionnaire was also part of a larger study [7] in which a more detailed validation was performed by means of the sino-nasal outcome test 20 German adapted version (SNOT-20 GAV) and an objective measurement of nasal patency via anterior rhinomanometry which has already been described in other studies [7, 15]. As all three evaluation systems showed similar results concerning the clinical outcome of the procedure, in this feasibility study only the questionnaire was employed in order to reduce the effort.

However, mucosal swelling of the inferior turbinates is part of the physiological vascular changes that take place during the nasal cycle and is therefore not easy to determine objectively. As a matter of fact, there is no definition of what constitutes an enlarged turbinate in terms of objective measurement, and the diagnosis is normally made by exclusion criteria when dealing with the sensation of nasal obstruction [16]. Subjective assessment of nasal obstruction provides important information about how the patient senses the severity of the symptoms. The lack of correlation of subjective scores of nasal obstruction with objective measures of nasal obstruction have partly led to the conclusion that objective measures such as rhinomanometry may be of limited clinical value [17].

One of the major drawbacks of the current trial is the fact that it does not provide long-term follow-up data. The long-term outcome in particular seems to be the critical issue with the laser treatments of the turbinates [18, 19]. For the 940 nm system as well as the Ho:YAG laser system, however, a previous study has shown promising long-term results for this indication [20]. However due to the small patient numbers and the lack of long-term data, it is not feasible to directly compare the method to other novel approaches [1, 21, 22]. Moreover, there is currently no clear consensus or “gold standard” in the literature indicating the most optimal technique for turbinate reduction and even the selection of an operative procedure remains controversial [23, 24]. This makes an appropriate evaluation or a comparison of novel techniques challenging. Nevertheless, laser reduction and radiofrequency reduction

Figure 1 Treatment and follow-up situations of 1940 nm Tm: fiber laser-assisted tissue reduction of hyperplastic turbinates in left and right nasal cavity. (A) *In-situ* situation before Privine® embedding. (B) Situation 15 min following decongestion (Privine®). (C) Coagulation of the tissue immediately after laser treatment and (D) reduced turbinate volume after wound healing and follow-up period of 28 days without decongestion.

Figure 2 Treatment and follow-up situations of 1940 nm Tm: fiber laser-assisted tissue reduction of hyperplastic turbinates in left and right nasal cavity. (A) *In-situ* situation before Privine® embedding. (B) Situation 15 min following decongestion (Privine®). (C) Coagulation of the tissue immediately after laser treatment and (D) reduced turbinate volume after wound healing and follow-up period of 42 days without decongestion.

Figure 3 Tm: fiber laser-assisted treatment of synechia. (A and B) Coagulation and cutting. (C) Situation immediately after laser-assisted treatment showing good coagulation without any bleeding.

seem to stand out as methods that can be applied under local anesthesia, providing minimal morbidity. For these reasons, the 940 nm diode laser was used for more than a decade for this indication and was regarded as standard laser practice [6, 12, 13, 20].

A further, minor shortcoming of this trial is the lack of histological studies to assess ultrastructural effects on the inferior turbinate mucosa to support or explain the excellent coagulation capabilities of this novel laser system as subjectively assessed by the operating surgeon. There is some published data on 940 nm diode laser tissue effects available that shows that in contrast to $\lambda=10,600$ nm, which is known to cause a superficial vaporization of the tissue with a broad carbonization zone and penetration depth of 0.1 mm, it provides deeper tissue penetration with a thin carbonization layer and pronounced coagulation zone up to 1–3 mm [6]. Histopathological changes following laser surgery, showed that the lamina propria was occupied by fibrous tissues, and that the number of vessels and seromucinous glands in the turbinates had decreased [25–27]. Some authors found that laser-assisted turbinate surgery disturbed mucociliary function [28, 29], whereas others found the postoperative mucociliary clearance to be unchanged [30].

However, observations in *in-vitro* experiments using 1940 nm laser-light interaction on kidney tissue showed both good tissue coagulation in non-contact with laser power values <10 W and excellent cutting properties [31]. These capabilities gave the motivation for cutting of intra-operatively diagnosed synechia in two nostrils. The laser

treatment process of coagulation of the synechia tissue to prevent bleeding while cutting is shown in Figure 3A and B; the resulting sealed tissue surface in Figure 3C.

As a result of experience with 1940 nm Tm: fiber laser interventions to reduce volume in the treatment of hyperplastic nasal turbinates by superficial coagulation, together with its easy handling and the possibility of minimally invasive surgery interventions for bloodless cutting, it can be concluded that the 1940 nm Tm: fiber laser shows potential for clinical use in ear, nose and throat (ENT)-related interventions for the benefit of the patient.

5 Conclusion

The 1940 nm Tm: fiber laser system offers an efficient alternative to conventional laser systems in treatment of nasal obstruction due to hyperplastic nasal turbinates. With respect to the conditions of this feasibility study, in this case series comparable clinical results are obtained with relatively low energy consumption as well as a significant reduction in the laser treatment time to the satisfaction of the patients. Further randomized clinical trials are needed to confirm these results and to extend the 1940 nm laser-energy application in the clinics.

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References

- [1] Chang CW, Ries WR. Surgical treatment of the inferior turbinate: new techniques. *Curr Opin Otolaryngol Head Neck Surg* 2004;12(1):53–7.
- [2] Mladina R, Risavi R, Subaric M. CO₂ laser anterior turbinectomy in the treatment of non-allergic vasomotor rhinopathia. A prospective study upon 78 patients. *Rhinology* 1991;29(4):267–71.

- [3] DeRowe A, Landsberg R, Leonov Y, Katzir A, Ophir D. Subjective comparison of Nd:YAG, diode, and CO₂ lasers for endoscopically guided inferior turbinate reduction surgery. *Am J Rhinol* 1998;12(3):209–12.
- [4] Serrano E, Percodani J, Yardeni E, Lombard L, Laffitte F, Pessey JJ. The holmium:YAG laser for treatment of inferior turbinate hypertrophy. *Rhinology* 1998;36(2):77–80.
- [5] Leunig A, Janda P, Sroka R, Baumgartner R, Grevers G. Ho:YAG laser treatment of hyperplastic inferior nasal turbinates. *Laryngoscope* 1999;109(10):1690–5.
- [6] Janda P, Sroka R, Baumgartner R, Grevers G, Leunig A. Laser treatment of hyperplastic inferior nasal turbinates: a review. *Lasers Surg Med* 2001;28(5):404–13.
- [7] Havel M, Sroka R, Leunig A, Patel P, Betz CS. A double-blind, randomized, intra-individual controlled feasibility trial comparing the use of 1,470 and 940 nm diode laser for the treatment of hyperplastic inferior nasal turbinates. *Lasers Surg Med* 2011;43(9):881–6.
- [8] Sroka R, Rösler P, Janda P, Grevers G, Leunig A. Endonasal laser surgery with a new laser fiber guidance instrument. *Laryngoscope* 2000;110(2 Pt 1):332–4.
- [9] Doganci S, Yildirim V, Demirkilic U. Does puncture site affect the rate of nerve injuries following endovenous laser ablation of the small saphenous veins? *Eur J Vasc Endovasc Surg* 2011;41(3):400–5.
- [10] Seitz M, Ruszat R, Bayer T, Tilki D, Bachmann A, Stief C, Sroka R, Reich O. Ex vivo and in vivo investigations of the novel 1,470 nm diode laser for potential treatment of benign prostatic enlargement. *Lasers Med Sci* 2009;24(3):419–24.
- [11] Schwarz T, von Hohenberg E, Furtwängler C, Rastan A, Zeller T, Neumann FJ. Endovenous laser ablation of varicose veins with the 1470-nm diode laser. *J Vasc Surg* 2010;51(6):1474–8.
- [12] Janda P, Sroka R, Mundweil B, Betz CS, Baumgartner R, Leunig A. Comparison of thermal tissue effects induced by contact application of fiber guided laser systems. *Lasers Surg Med* 2003;33(2):93–101.
- [13] Janda P, Sroka R, Tauber S, Baumgartner R, Grevers G, Leunig A. Diode laser treatment of hyperplastic inferior nasal turbinates. *Lasers Surg Med* 2000;27(2):129–39.
- [14] Newman J, Anand V. Applications of the diode laser in otolaryngology. *Ear Nose Throat J* 2002;81(12):850–1.
- [15] Baumann I, Blumenstock G, DeMaddalena H, Piccirillo JF, Plinkert PK. Quality of life in patients with chronic rhinosinusitis: validation of the Sino-Nasal Outcome Test-20 German Adapted Version. *HNO* 2007;55(1):42–7.
- [16] Grymer L. The management of enlarged turbinates. In: Gleeson MJ, Browning GG, Burton MJ, Clarke R, Hibbert J, Jones NS, Lund VJ, Luxon LM, Watkinson JC, editors. *Scott-Brown's otorhinolaryngology: head and neck surgery*. London: Hodder Arnold Publishers; 2008, pp. 1589–92.
- [17] Yaniv E, Hadar T, Shvero J, Raveh E. Objective and subjective nasal airflow. *Am J Otolaryngol* 1997;18(1):29–32.
- [18] Passàli D, Passàli FM, Damiani V, Passàli GC, Bellussi L. Treatment of inferior turbinate hypertrophy: a randomized clinical trial. *Ann Otol Rhinol Laryngol* 2003;112(8):83–8.
- [19] Rejali SD, Upile T, McLellan D, Bingham BJ. Inferior turbinate reduction in children using Holmium YAG laser – a clinical and histological study. *Lasers Surg Med* 2004;34(4):310–4.
- [20] Janda P, Sroka R, Betz CS, Baumgartner R, Leunig A. Comparison of laser induced effects on hyperplastic inferior nasal turbinates by means of scanning electron microscopy. *Lasers Surg Med* 2002;30(1):31–9.
- [21] Nease CJ, Kreml GA. Radiofrequency treatment of turbinate hypertrophy: a randomized, blinded, placebo-controlled clinical trial. *Otolaryngol Head Neck Surg* 2004;130(3):291–9.
- [22] Cavaliere M, Mottola G, Iemma M. Monopolar and bipolar radiofrequency thermal ablation of inferior turbinates: 20-month follow-up. *Otolaryngol Head Neck Surg* 2007;137(2):256–63.
- [23] Bhandarkar ND, Smith TL. Outcomes of surgery for inferior turbinate hypertrophy. *Curr Opin Otolaryngol Head Neck Surg* 2010;18(1):49–53.
- [24] Willatt D. The evidence for reducing inferior turbinates. *Rhinology* 2009;47(3):227–36.
- [25] Schmidt J, Zalewski P, Olszewski J, Olszewska-Ziaber A. Histopathological verification of clinical indications to partial inferior turbinectomy. *Rhinology* 2001;39(3):147–50.
- [26] Elwany S, Abdel-Moneim MH. Carbon dioxide laser turbinectomy. An electron microscopic study. *J Laryngol Otol* 1997;111(10):931–4.
- [27] Olszewska E, Sieskiewicz A, Kasacka I, Rogowski M, Zukowska M, Soroczyńska J, Rutkowska J. Cytology of nasal mucosa, olfactometry and rhinomanometry in patients after CO₂ laser mucotomy in inferior turbinate hypertrophy. *Folia Histochem Cytobiol* 2010;48(2):217–21.
- [28] Sapçı T, Sahin B, Karavus A, Akbulut UG. Comparison of the effects of radiofrequency tissue ablation, CO₂ laser ablation, and partial turbinectomy applications on nasal mucociliary functions. *Laryngoscope* 2003;113(3):514–9.
- [29] Cassano M, Granieri C, Del Giudice AM, Mora F, Fiocca-Matthews E, Cassano P. Restoration of nasal cytology after endoscopic turbinoplasty versus laser-assisted turbinoplasty. *Am J Rhinol Allergy* 2010;24(4):310–4.
- [30] Pang YT, Willatt DJ. Laser reduction of inferior turbinates in children. *Singapore Med J* 1995;36(5):514–6.
- [31] Khoder WY, Zilinsberg K, Waidelich R, Stief CG, Becker AJ, Pangratz T, Hennig G, Sroka R. Ex vivo comparison of the tissue effects of six laser wavelengths for potential use in laser supported partial nephrectomy. *J Biomed Opt* 2012. <http://dx.doi.org/10.1117/1.JBO.17.6.068005>.