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Endonasal and transcanalicular Er:YAG laser dacryocystorhinostomy*

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SUMMARY

In the last 10 years different types of lasers were used for dacryocystorhinostomy (DCR). Between April 1998 and August 1999, a fibreoptic erbium laser DCR was performed on 12 patients. Eight cases were for a presaccal stenosis and 4 cases for a postsaccal stenosis. An erbium laser with a specially designed handpiece was used endonasaly and transcanaliculary. Preoperative epiphora was present in all patients. Double bicanalicular nasal silicone tubes were placed during surgery in all cases. The 3 cases of postoperative failure included 2 cases of presaccal stenosis and 1 case of the postsaccal group; failure manifested with recurrent epiphora / dacryocystitis ; the onset of symptom recurrence varied from 9 weeks to 11 weeks postoperatively. Laser-assisted DCR includes the avoidance of a cutaneous incision, excessive tissue injury, the advantage of short operation time and precision. Suitable indications for the erbium laser are stenoses in the canaliculi, in the sac, but also for bone lacrimal bone cutting.

Key words: lacrimal drainage system, nose, eye

INTRODUCTION

Chronic stenosis of the nasolacrimal duct system can be surgically treated by external or endonasal dacryocystorhinostomy (DCR) (Hartikainen et al., 1998; Häusler et al., 1999a). Endonasal DCR is performed in many places as an endoscopic operation with the aid of rigid optics. It can also be done as a microsurgical procedure under a binocular operating microscope. Massaro et al. (1990) published the first article on endonasal laser-assisted DCR. They proposed that laser allows a discrete delivery of energy to the target site without causing surrounding tissue damage. In the last 10 years, different laser delivery systems have been used to perform DCR on a large number of patients (Gonnering et al., 1991; Reifler, 1993; Woog et al.,1993; Kong et al., 1994; Metson et al., 1994; Hartikainen et al., 1998; Szubin et al., 1999). Endoscopic laser DCR enables an obstructed lacrimal sac to be opened through an intranasal approach, avoiding the need for skin incision. In cases of presaccal stenosis (canalicular) laser-endoscopic recanalisation can be useful (Christenbury, 1992; Levin and Stromogipson, 1992; Kuchar et al., 1999).

In this study an erbium laser with a specially designed handpiece was used for pre- and postsaccal stenoses of the lacrimo-nasal drainage system. The results are compared to other laser sources used so far in DCR. The advantages and disadvantages of the different laser systems are discussed.

MATERIAL AND METHODS

Between April 1998 and August 1999, a fibreoptic erbium laser DCR was performed on 12 patients (8 women and 4 men; ages 39-80 years) under general anesthesia. In 8 cases, there was stenosis of the superior, inferior or common canaliculus (presaccal stenosis); in 4 cases, there was stenosis of the lacrimal ducts (postsaccal stenosis). The causes included obstruction of the lacrimal ducts caused by midfacial trauma (7), recurrent infections of the nose or the paranasal sinuses (4) and stenosis developed after a rhinological operation (1). A dacryocystogram was obtained in 12 patients either by digital subtraction or magnetic resonance imaging. This enabled us to identify the exact site of the stenosis and to distinguish between canalicular and ductal stenosis of the nasolacrimal duct system. The follow-up was 11-27 months. The criteria of improvement or postoperative comfort was epiphora and active (with 5% sodium fluorescence) and passive rinsing (sodium chlorid water 0.9%) of the nasolacrimal system.

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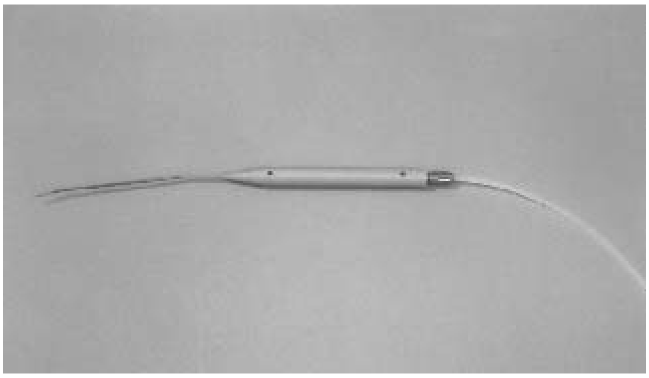

Figure 1.
a.) Visible is our optical Er:YAG laser handpiece.
b) Close-up view of the zirconium-fluoride fibre (core diameter 350 μm).

A pulsed Er:YAG laser (Erbium:yttrium aluminium garnet; wavelength $\lambda = 2.94 \mu m$) system was used (Häusler et al., 1999 a,b). The laser was operated in the free-running mode at a repetition rate set between 1 Hz and 8 Hz. The laser was designed in such a way that changing the pulse duration varied the pulse energy at a rate of 40mJ/100μs. Due to the high absorption of Er:YAG laser radiation in quartz (10 dB/cm attenuation), no commercially available fibre delivery system could be used. Therefore, an optical fibre handpiece consisting of a zirconium-fluoride fibre (ZrF_4, core diameter 350 μm, LeVerre Fluore, France) connected to a coaxially mounted low-OH quartz tip (length 1 cm, core diameter 400 μm) was developed (Figure 1a,b). The hygroscopic nature and brittle structure of ZrF_4, made this protection necessary. The fibre applicator was designed in such a way that the quartz end piece could easily be exchanged in case of damage but the expensive ZrF_4 fibre is reused. In addition, in two cases a sapphire fibre (core diameter of 425 μm) was used for transmission. Cutting of soft tissue was performed at pulse durations of 250 μs corresponding to pulse energies of 100 mJ, whereas the perforation of the bone required pulse energies above 200 mJ.

The cost of the system is distributed in one part to the laser equipment (Euro: ~20.000) and in one part to the fibre (Euro: ~1300). The fibre can be resterilised (ethylen gas 30 degree; 10 hours), but after 5-10 procedures a new one is used. The operating room must be classified as a laser room with a declaration on the door of laser use, possibility for laser smoke aspiration and fire prevention. Goggles for eye protection are also necessary. The patient's eye must be protected with a vitamin A cream and the eyelid closed as much as possible. For the transcanalicular procedure, laser shots are released only when the tip of the microhandpiece probe is inserted in the canaliculus.

The microscopic DCR was performed under general anesthesia by means of a fixed nasal speculum (Figure 2). Two operation techniques were possible by virtue of our microhandpiece: in cases of postsaccal (ductal) stenosis, the lacrimal bone was removed by repetitive endonasal laser shots (143 J/cm^2) after preparation of a mucosal flap. On average ~500 pulses were required to cover at least a 1 cm^2 area. By means of gentle pressure on the excavators inserted in the nasolacrimal ducts, the medial wall of the lacrimal sac was stretched toward the nose in the form of a tent. Using again the Er:YAG laser, the sac was incised from bottom to top until the nasolacrimal duct excavators were visible. The medial wall of the lacrimal sac was then excised. In all the cases, the middle turbinate was left in place.

In cases of canalicular or saccal stenosis, we introduced the laser tip on the inferior or superior lacrimal point (Figure 2). It was possible to create "new" canaliculi under endonasal control after "cutting" the lacrimal bone from the nose. In case of a canaliculus stenosis, more than 40 laser shots were required. It took about 10-20 seconds to penetrate the blocked system using a total laser energy of about 10 J.

In two cases the middle turbinate was partially resected. A microdebrider was never used during any part of these surgeries. In all these cases long-term bicanalicular silicone tubes (Buerki innomed, CH-9442 Berneck, Switzerland) were inserted (Häusler and Caversaccio; 1998). They have the advantage not only of maximum permanent dilatation of the canaliculi but also of allowing the aspiration of tears by capillary force (Figure 3). No nasal packing was used. The silicone tubes were removed after 9 months. Patients were given a perioperative intravenous antibiotic prophylactic (e.g. amoxicillin and clavulanate potassi-

Figure 2. Surgical arrangement during transcanalicular DCR. Operative procedure under the binocular microscope and exposition of the nasal cavity by the self-holding nasal speculum with a flexible tensioning arm. In the right hand, the surgeon holds the Er:YAG laser handpiece. The surgeon controls the position of the tip from the laser through the endonasal microscopic view.

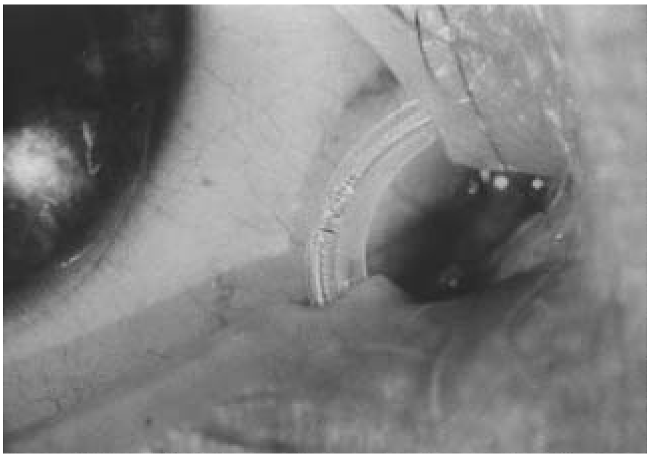

Figure 3. Close-up view of two parallel bicanalicular silicone tubes inserted in the upper and lower lacrimal puncta. There is no visible inflammatory reaction to the tubes.

um). For one week after the operation, the eyes were treated with anti-inflammatory eyedrops (e.g. fluorometholone and neomycin sulfate). Patients were hospitalised for an average of one day postoperatively.

RESULTS

The Er:YAG laser microhandpiece proved to be a comfortable and precise instrument for DCR. Endonasal removal of the lacrimal bone was performed without complication. To create new canaliculi, the Er:YAG laser microhandpiece was easy in a scar tissue, no skin incision was necessary, and no damage to surrounding tissue occurred.

Ocular or orbital injuries did not occur. In 2 cases we saw a slight local post-operative synechia of the middle turbinate and the lateral nasal wall. Laser light breaking through the medial lacrimal region in canalicular stenosis gives intraoperatively little spotting damage to the middle turbinate mucosa which disappears after several days and was not reponsible for the synechia. To prevent this situation, a small moist film between the middle turbinate and the lacrimal region will be useful. Operating times are initially longer (one hour with nasal decongestion) because of the time needed to learn to work with the laser system; however, after the first few operations, the surgeon finds his rhythm, and surgery can progress at an even pace (~45 minutes with decongestion). We did not find that the laser reduced the time needed for DCR in comparison to conventional DCR operation. The length of postoperative follow-up ranged between 11 and 27 months. The patients were checked at approximately 3 month intervals for lacrimal canal patency either passively by flushing or actively by proof of the sodium fluorescent effect in the nose. The success of treatment was assessed according to each patient's freedom of epiphora and according to active and passive flushability of the ducts (Table 1). The tubes were left in place as long as possible (9-12 months).

Table 1. Properties of epiphora, active (sodium chloride solution 0.9% and passive (sodium fluorescence solution 5%) flushability of the nasolacrimal system.

	Canalicular stenosis (n=8)	Ductal stenosis (n=4)
A. Epiphora	2	1
B. Passive rinsing without problems	5*	3
C. Active rinsing without problems	6	2**

* One patient was not tested with the fluorescein eye drops
** One patient refused the active rinsing with the saline solution

Out of the 4 patients who were surgically treated for ductal stenosis, 3 became free of discomfort (epiphora) and in 1 case a second operation was necessary. Of the 8 patients with canalicular stenosis, 6 became symptom free after one procedure. A second operation was performed in 2 cases where the epiphora persisted.

DISCUSSION

In contrast to the classic external DCR, the microscopic or endoscopic transnasal method is a minimally invasive procedure with no negative cosmetic effects. In general, the prognosis is better in postsaccal stenosis than in presaccal stenosis (Metson et al., 1994; Häusler and Caversaccio, 1998; Kuchar et al., 1999). First research and application of laser in otorhinolaryngology was performed by means of a CO_2 laser in the area of the larynx (Strong and Jako, 1972). Since 1990, different types of lasers have been used for DCR (Massaro et al., 1990). Ideally, a laser used for DCR and particularly for transcanalicular lasers DCR should provide high precision with limited thermal damage to collateral tissues, adequate hemostasis, soft and hard tissue (bone)-cutting capabilities, high ablation efficiency and must be transmitted through an optical fibre. The effect of a surgical laser on tissue is strongly dependent on the wavelength of the laser since it defines how strong the laser radiation is absorbed and scattered in the irradiated tissue. For efficient and precise ablation with little adjacent thermal tissue damage, it is desirable to have strong absorption and short irradiation times, so that the optical energy which is converted to heat upon absorption is confined to a relatively small volume. Several lasers have been used with more or less success, but it is difficult to find a laser which accomplishes all the mentioned conditions. Depending on the laser parameters, laser treatment can involve potential risks for the eye caused by direct laser irradiation, heating effects and/or shock and pressure waves, which occur during pulsed application. Advantages of laser assisted-DCR operations are the relatively short surgery time, avoidance of a cutaneous incision (presaccal stenosis), excessive tissue injury, and reduced potential for mucosal bleeding.

The transcanalicular approach has recently been developed because lasers offer the advantage of treating canalicular stenoses in a minimally invasive procedure (Christenbury, 1992; Kuchar et al., 1999; Eloy et al., 2000). A disadvantage can be the production of an osteotomy fistula too small for use especially when the operation is done exclusively transcanaliculary. In this case, anomaly of the nose, such as an hypertrophy of a middle turbinate, nasal polyps or a septum deviation, cannot be treated (Saint Blancat et al., 1996). The exact role for associated nasal

Table 2. Different lasers used for DCR.

Name	Color	Wave-lengths (mm)	Author
Argon	Blue	488-514	Massaro et al., 1990; Boush et al., 1994
KTP	Green	532	Gonnering et al., 1991; Levin and Stromogipson,1992; Reifler 1993; Mickelson et al., 1997; Müllner and Wolf, 1999; Müllner et al., 2000
Nd:YAG	Infrared	1064	Seppä et al., 1994; Saint Blancat et al., 1996; Patel et al., 1997; Pearlman et al., 1997
CO_2	Infrared	10600	Gonnering et al., 1991
CO_2+Nd:YAG			Seppä et al., 1994; Hartikainen et al., 1998
Ho:YAG	Infrared	2100	Woog et al., 1993; Metson et al., 1994; Hehar et al., 1997; Gleich et al., 1995; Szubin et al., 1999
Er:YAG	Infrared	2940	Emmerich et al., 1999; Häusler et al., 1999a; Meyer-Rüsenberg et al., 1999; Müllner and Wolf, 1999; Brémond-Gignac et al., 1999; Kuchar et al., 2000

surgery for the outcome of DCR is not clear (Metson et al., 1994). DCR under local anesthesia with intravenous sedation seems to be possible where the patient can be treated as an outpatient. This is of great importance both for patient satisfaction and for economic use of resources (Hehar et al., 1997). Currently, several surgical lasers are used for DCR (Table 2).

The continuous wave (cw) argon laser (16 W) with a 300 μm quartz fibreoptic laser catheter was used in the beginning of the nineties with a success rate of 70% (pre- and postsaccal stenosis) (Boush et al., 1994). Energy absorption takes place mainly in pigmented tissues (hemoglobin, melanin) and leads to a strong heat effect in the adjacent tissue. Argon radiation can be applied through commercially available quartz fibres, which allows a precise and localised application through a microhandpiece. Christenbury (1992) first described the formation of a lacrimal-to-nasal fistula by delivery of argon laser energy through the superior and inferior canaliculi. High energy (e.g. 16 Watt) of the argon-blue laser was required to make an adequate opening, but undesirable injury of collateral tissue occurred (Massaro et al., 1990, 1992). Szubin et al. (1999) used an argon- HGM laser (HGM Inc. Salt Lake City UT, USA) with a success rate of 97%.
The KTP laser can be delivered like the argon laser through small flexible quartz fibreoptics (e.g. 300 μm) with high power density, enabling coagulation and vaporisation of soft tissue. Gonnering et al. (1991) used a KTP laser (8-10 Watt) in a non-contact mode to achieve hemostasis or in the so called near-contact mode for tissue vaporisation. The success rate was about 60% in revision cases (Mickelson et al., 1997) and increased to 68 % in primary cases (Reifler, 1993). Another application for the use of the KTP laser is endolacrimal surgery combined with an endolacrimal endoscope (Müllner et al., 2000). Disadvantages of the argon and the KTP laser, both emitting radiation in the human visible range, are the limited bone-cutting properties and that the surgeon is required to wear coloured eye protection impairing visibility.

The Nd:YAG laser with a 600 μm fibre contact probe was used for transcanalicular surgery (2-7 Watt) (Saint Blancat et al., 1996 ;Pearlman et al., 1997). The success rate was between 46% (Patel et al., 1997), 70% (Saint Blancat et al., 1996) and 85% (Pearlman et al., 1997).
The CO_2 laser radiation which is also absorbed in water mainly by bone minerals (hydroxyapatite and calcium phosphate) has been noted to efficiently ablate bone in a dry operation field (Forrer et al., 1993). The ablation process ceases as the tissue becomes desiccated and a char is formed, since although the mineral components are the main absorber, water is the driving force for the explosive ablation process using a superpulsed CO_2 laser. A main drawback of the CO_2 laser is the lack of high transmission optical fibres. It's radiation must be internally reflected in hollow waveguides or focused from an articulated delivery arm down a waveguide, which must be flushed with an inert gas to keep the distal reflective mirror free from char from the laser plume (Gonnering et al., 1991).
Seppä et al. (1994) performed an endonasal combined CO_2-Nd :YAG (5-10 Watt) laser DCR with a success rate of 67% after a single attempt (pre- and postsaccal stenosis). Combined CO_2 and Nd:YAG laser radiation caused peripheral thermal injury to non target tissues and is also not transmittable through fibres, which makes this laser combination not optimally applicable to transcanalicular surgery (Nuss et al., 1988; Hartikainen et al., 1998).
The pulsed Ho :YAG is capable of ablating soft and hard tissue since its radiation is strongly absorbed by water. The collateral thermal damage was shown to be limited to a few hundreds of microns. The ablation process is due to the strong absorption in water driven by explosive vaporisation. An audible snap is produced, and an explosion of tissue occurs, ejecting portions of the tissue and dissipating further energy (Gleich et al., 1995). The average Ho:YAG laser power ranged from 2,5 to 10 W. Laser energy was delivered through a 400 μm-diameter low-OH quartz fibre. The laser energy amounted to 1 J per pulse at a pulse rate of 10 Hz (Woog et al., 1993). In most cases the Ho :YAG laser was used endonasal. The success rate without differentiating between canalicular and postsaccal stenosis was 82% (Woog et al., 1993), 85% (Metson et al., 1994) and 79% (Hehar et al., 1997).
The Er:YAG laser is, in contrast to all laser sources previously mentioned, characterised by excellent cutting properties in soft and hard tissue. By virtue of its about 300 times stronger absorption in water compared to Ho:YAG laser radiation, the deposited energy remains limited to a very restricted volume, which makes this laser an outstandingly precise microsurgical instrument (Kautzky et al., 1992; Frenz et al., 1996). This is confirmed by the very restricted adjacent tissue thermal injury of 10-20 μm (Romano et al., 1993; Häusler et al., 1999b). For pulse energies higher than about 200 mJ, the explosive bone ablation process is highly efficient. In addition, Er:YAG laser radiation can be transmitted through optical fibres, a prerequisite for minimally-invasive surgical procedures. A drawback of the Er:YAG laser radiation, however, is its limited possibility to coagulate the vessels. Meyer-Rüsenberg et al. (1999), Kuchar et al.(1999) and Brémond-Gignac et al. (1999) used an Er:YAG laser (Sklerostom™, Schwind, Kleinostheim, Germany) for a transcanalicular proce-

dure in combination with an endoscope. Due to the relatively low pulse energy used, these authors had difficulties in creating sufficient bony fistulas as is necessary in laser DCR procedures. With our Er:YAG laser system, using optimised laser parameters, bone cutting was performed without difficulties.

CONCLUSION

The Er:YAG laser is suitable for canalicular stenosis and saccal stenosis but also for postsaccal stenosis. The fibre system and the handpiece allow an endonasal and transcanalicular procedure. Our preliminary clinical results predict a good future for the erbium laser for DCR, but also for further otorhinolaryngologic applications.

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