ORIGINAL ARTICLES

Endocanalicular Dacryocystorhinostomy (E-DCR): Relevance of Materials Standardization for Outcomes

José Maeso-Riera[a] and M. Teresa Sellarès-Fabrés[b]
[a]Departamento de Láser, Centro Médico Delfos, Barcelona, Spain
[b]Servicio de Oftalmología, Consorci Sanitari Parc Taulí, Sabadell, Barcelona, Spain

Introduction and objectives: After 5 years' experience with endocanalicular dacryocystorhinostomy (E-DCR) using diode laser, the introduction of new materials has led to significant technical differences, thus giving rise to this study to evaluate them.
Material and method: We compare the behaviour of 2 different kinds of laser guide fibre (silica-fluoropolymer-tefzel and silica-silica-polyamide), using the same laser generator, on organic tissues from fresh animal carcases, and we summarize the clinical behaviour of the new materials in lachrymal surgery cases.
Results: We have seen significant differences in the clinical behaviour of the 2 kinds of laser guides, namely the proposed new materials have a worse behaviour on organic tissues than their physical characteristics might theoretically have suggested. Thus, the use of different guide materials could lead to relevant differences in terms of surgical results, as well as in the comparison of the outcomes of series performed by different surgeons.
Conclusions: It is necessary to determine standards for the materials recommended for this surgery, not only for easier technical performance and better effectiveness, but also to allow comparison of results from different authors.

Key words: Lachrymal duct obstruction. Dacryocystorhinostomy. Endocanalicular. Laser.

Dacriocistorrinostomía endocanalicular (DCR-E): importancia de la estandarización de materiales en los resultados
Introducción y objetivos: Después de un periodo de 5 años de experiencia con la dacriocistorrinostomía endocanalicular (DCR-E) con láser diodo, la introducción de nuevos materiales ha originado diferencias técnicas significativas que motivan el presente trabajo para su evaluación.
Material y método: Se compara el comportamiento de dos tipos distintos de fibra de guía de láser (sílice-fluoropolímero-tefzel y sílice-sílice-poliamida), usando un mismo generador, sobre tejido orgánico de cadáver animal fresco, y se resume el comportamiento clínico de los nuevos materiales en una serie de casos de cirugía lagrimal.
Resultados: Hemos observado diferencias relevantes en el comportamiento clínico de dos tipos distintos de fibras de guía de láser, y se objetiva que los nuevos materiales propuestos tienen un comportamiento sobre tejido orgánico peor de lo que sus características físicas teóricas hacen suponer. Así, la utilización de diferentes materiales de guía puede implicar diferencias relevantes en los resultados de la cirugía, así como en el momento de evaluar estas técnicas en diferentes series realizadas por distintos cirujanos.
Conclusiones: Debe buscarse una estandarización de los materiales recomendados para estas cirugías, tanto por su utilidad y efectividad clínica como en la comparación de resultados de diferentes series.

Palabras clave: Obstrucción lagrimal. Dacriocistorrinostomía. Endocanalicular. Láser.

INTRODUCTION

Endocanalicular lachrymal surgery using diode laser has for some years been demonstrating its effectiveness in the treatment of obstructive diseases of the lachrymal system. For those of us who use the technique regularly, it has proved speedy, with scant morbidity and a high degree of long-term effectiveness.[1-3]

Nonetheless, recent experience has shown that the material used must be standardized in order to be able to compare series and expertise at different centres. This involves not only the application of various types of laser, but also changes in the material of the laser guide fibres that may give quite different surgical results.

Correspondence: Dr. J. Maeso Riera.
Cisterna, 2. 08221 Terrassa. Barcelona. España.
E-mail: 24024jmr@comb.es

Received April 7, 2008.
Accepted for publication April 29, 2008.

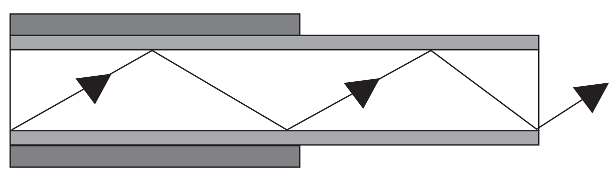

Figure 1. Structure and composition of the conduction fibres for the diode laser and theoretical characteristics of the fibres currently used.

All laser guide fibres are made up of a core and a cladding. The difference between the refraction index of the core and that of the cladding means that the light beam is confined in the core and is transmitted with very little loss (Figure 1).

The core is always made of silica and withstands temperatures of over 1000ºC. Depending on the material used in the cladding, we will have different aperture numbers (divergence of the beam).

Finally, an external layer called the jacket gives the fibre elasticity and prevents it from breaking. This may also be made of various materials.

We began with this technique at the end of 2003, using silica-fluoropolymer-tefzel, the same kind we continue to use currently. Since then, silica-silica-polyamide fibres have made their appearance and should theoretically behave better. The output angle is lower, so they concentrate the laser beam better and minimize the lesion around the treatment channel. They withstand higher temperatures, so the fibres' risk of ignition is lower and can be used more than once, as they can be sterilized at high temperatures. Their unit cost is somewhat higher, but they also have the advantage of being re-sterilized several times (up to 5, as they come with a usage counter), making the cost per case a little lower.

Surgical practice, however, does not coincide with the theoretical data and these fibres run up against technical difficulties that we will analyze here as they may, for several reasons, complicate the performance of dacryocystorhinostomy (DCR).

In the first cases operated on with the new fibres, we observed unexpected behaviour, with losses of the guide light, appearance of ghost images in areas of the nasal fossa wall when the guide was not really there, the increase in light when discharging was very weak, which did not help us to locate it, etc. On the other hand, we observed that we needed more power, longer times and additional impacts to be able to finish our surgery, entailing greater thermal lesion and a larger local inflammatory reaction.

The handling characteristics of both fibres in terms of malleability, rigidity and directionability are very similar. Nonetheless, the increased total power needed in the silica-silica fibres might lead to fears of a greater risk of iatrogenic canalicular damage.

For all these reasons, we have decided to study the behaviour of these materials and assess in practical terms the results of each kind so as to be able to determine their practical application in surgery.

MATERIAL AND METHOD

A 980 nm diode laser (Multidiode S15 OFT from INTERmedic, Spain) has been used as the generator.

We have studied the behaviour of 2 different fibres: 600 μm silica-fluoropolymer-tefzel and 600 μm silica-silica-polyamide (INTERmedic). We did not feel it was necessary to evaluate other materials as the first type is the one used until now and the second is the one that has started to be recommended for lachrymal surgery.

For the performance of the experimental study, it was decided to use fresh animal carcase tissue, as its characteristics are similar to those in live tissue when heated to temperatures close to 37ºC.

Three types of bone were chosen: thick cortical bone to evaluate the capacity for penetration and the thermal behaviour of the fibres; 4 mm thick spongy bone to evaluate the behaviour of both fibres in osteotomy manoeuvres; and lamb's head for practising DCR.

On cortical bone, the laser's penetration capacity (AMI micrometer, Australia, with a resolution of 0.01 mm) and the fibres' thermal behaviour (INFRACAM FLIR thermographic camera, Sweden) were measured using different parameters for time, pulse and laser power: continuous mode, 10 s/3 s (shot/pause) at 10 W of power; pulses of 600 ms/600 ms, 15 W; and pulses of 500 ms/500 ms, 15 W.

On spongy bone, we worked with fixed pulse and power parameters to evaluate the total amount of energy needed with each fibre to achieve osteotomy. Working with pulses of 500 ms/500 ms at 10 W of power, a total of 10 osteotomies were performed with each type of fibre.

On fresh lachrymal systems, the variables studied were time and total energy, and the characteristics of the ostium achieved with each type of fibre were observed, working with pulses of 500 ms/500 ms, at 10 W of power.

Finally, we recorded these same variables in 10 clinical cases of surgery performed with silica-silica-polyamide fibres, and compared them with those already known from our habitual series.

RESULTS

In the initial inspection of both guides, the first thing we observed was that the real output angle of the laser does not correspond exactly with the theoretical value (Figure 2). Thus, the real working angles of both fibres are more similar than the theory indicates, although it is true that the output angle of the silica-fluoropolymer fibre is greater.

Test on Solid Cortical Bone (Section of Cow's Femur). Penetration and Thermal Behaviour of the Fibres (Figure 3)

A first series of three shots at 10 W of power with a continuous pulse of 10 s, with a 3 s rest period.

The silica-fluoropolymer-tefzel fibre reached temperatures of over 300ºC, exceeding the thermographic camera's background scale. During the third shot, the heat ascending through the fibre caused the ignition of the tefzel jacket and rendered the fibre useless as its core was affected. This occurred after 27 s of firing.

The silica-silica-polyamide fibre also attained a temperature of over 300ºC. The jacket became gradually carbonized but did not ignite and remained whole throughout the series.

A second series of shots were fired in pulses of 650 ms/650 ms (pulse/pause) at 15 W of power, achieving a total of 1000 J of energy emitted. Lower local temperatures were observed with both fibres, without exceeding 80ºC and without any problems in their components.

The third series of shots was with pulses of 500 ms/500 ms (pulse/pause) at 15 W of power, achieving a total of 1000 J of energy emitted. Similarly, the local temperatures were lower, without exceeding 80ºC at any time. We observed that this pulse/pause relationship obtained a greater degree of penetration, without differences between the 2 fibres.

No difference was observed in any of the series between the 2 fibres with regard to the depth achieved in cortical bone, although the 500 ms/500 ms pulse/pause relationship seems to be favourable in terms of the ratio of penetration to thermal effect.

Osteotomy on 4 mm Thick Spongy Bone (Bird Sternum)

Carried out in pulsed mode, with pulse/pause parameters of 500 ms/500 ms at 10 W of power.

Two series of 10 osteotomies were performed with each type of fibre, striving to maintain identical bone thicknesses for both.

The osteotomies achieved with the silica-fluoropolymer fibres had a mean total energy of 200 J, with 35 pulses and a total laser exposure time of 19 s.

With silica-silica fibres, the mean total energy required was 252 J, with 42 pulses and 25 s.

Dacryocystorhinostomy on the Lachrymal System of a Fresh Animal Carcase (Lamb's Head)

The lachrymal route was located by means of the laser guide fibre, establishing a trajectory perpendicular to the nasal wall in order to progress towards the fossa. A DCR procedure was then carried out following normal techniques, working with pulses of 500 ms with pauses of 500 ms at 10 W of power; the progression imaging was monitored by a 0° endoscope.

Ample osteotomy was achieved with silica-fluoropolymer fibres using a mean of 500 J. The silica-silica fibres allowed us to complete osteotomy with a mean of 648 J.

The progression imaging varied between the 2 fibres (Figures 4A and 4B).

With the silica-fluoropolymer fibre, it was possible to monitor the guide light constantly and the emergence of carbonization crust in front of the fibre's progress was not

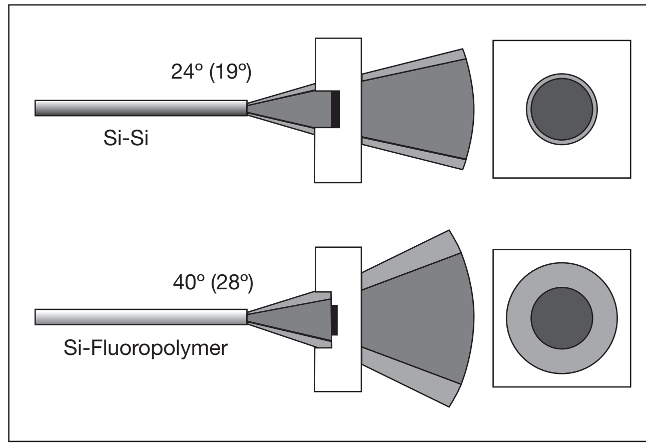

Figure 2. Differences seen between the theoretical output angle of the beam and the real angle in brackets. Alongside is the diagram illustrating the observation by transillumination of the ratio between the bone crust and the guide spot for each type of fibre.

Series 1. 10 s/3 s; 10 W
Series 3. 500 ms/500 ms; 15 W; 1000 J
Series 2. 650 ms/650 ms; 15 W; 1000 J

Figure 3. Test on cortical bone. It was seen that the ability to penetrate into solid bone was greater when working with pulses of 500 ms/500 ms (series 3). The image of crust and cauterization (pale halo) is similar with both kinds of fibre, although the longer the pulse lasts, the greater this is.

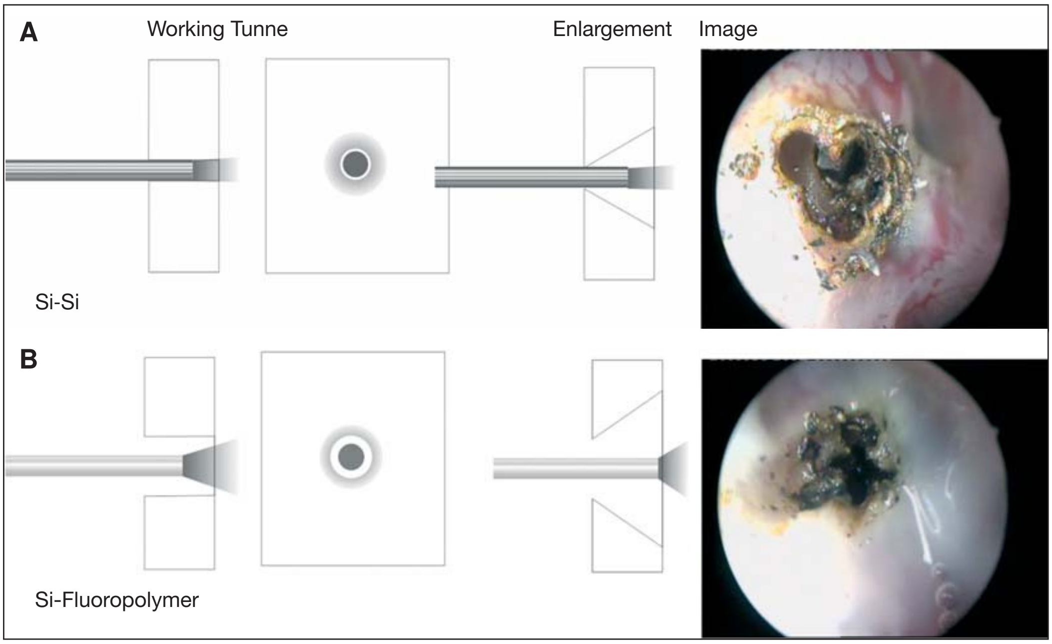

Figure 4. Diagram of the working behaviour of both fibres. A: silica-silica; we create a very narrow channel, with a highly focalized thermal effect; the room to manoeuvre is less and the thermal lesion is more marked. B: silica-fluoropolymer; the channel created is wider, allows better manoeuvrability and the thermal lesion is smaller. Si indicates silica.

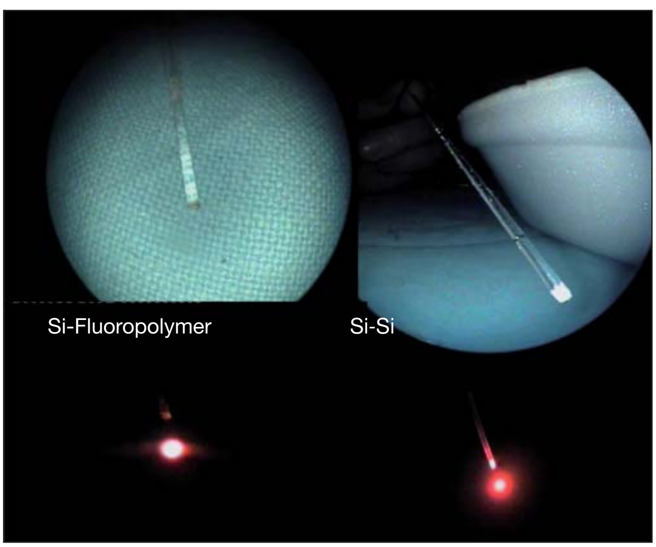

Figure 5. Appearance of the tip of both fibres and the final spot after the same amount of work.

observed. Furthermore, progress was made through a tunnel that allowed, thanks to its larger diameter, good mobility of the guide fibre and facilitated the enlargement of the osteotomy through the confluence of the different trajectories.

With silica-silica fibres, the clinical observations of the surgical cases were confirmed. The advance of the fibre generated a carbonization crust in front of the tip of the optical fibre, which gave rise to the disappearance of the guide light and the emergence of reflections outside the progression axis. The diameter of the bone tunnel through which we were progressing was very close to the diameter of the fibre, which became trapped several times. For this reason, to achieve a correct osteotomy, we had to perform several parallel perforations ("watering can" appearance), so it was more complex to make them flow together into one of sufficient size.

We were able to make an additional observation, as we found that the tip of the fibres behaved differently after working with them. The silica-fluoropolymer fibre was better at keeping its tip whole, flat, unmelted, with better definition of the spot. In the silica-silica fibre the tip melted to a greater extent, became rounded and the spot of the guide dispersed more as it was used (Figure 5).

Clinical Experience. Diode Laser Surgery With Silica-Silica Guide, Continuous Mode at 10 W of Power

Table summarizes the parameters we have obtained in the 10 clinical cases carried out with silica-silica fibres. Both the total energy needed to perform the surgery and the number of impacts or the total laser exposure were greater than those in the series with habitual treatment performed with silica-fluoropolymer fibres, both at our centre and reported by other authors.[1-4]

Of the 10 eyes operated on, one could not be completed due to loss of the guide spot; it was not possible to align progression correctly.

On the other hand, the number of impacts and the mean total energy necessary were higher than those we had normally required with silica-fluoropolymer guides.

No long-term canalicular lesions were observed.

DISCUSSION

Based on the papers already well known with the medium- and long-term results with diode laser endocanalicular lachrymal surgery, we can say that this technique has brought great advantages, with perfectly acceptable results, since we started practising it in 2003. These outcomes are shared with other authors in both initial surgery and review surgery after failure of previous techniques.[2-5]

However, the experience of different surgeons starting to use the technique did not seem to be so satisfactory. Over and above the necessary learning curve at the beginning, the results seemed not to improve and the technical difficulties reported seemed excessive. For our part, in the training courses we were offering working recommendations that were valid for one type of material but not for the other, as we have since confirmed.[6]

We have not been able to find any references in the literature on similar studies with which to compare our results. Furthermore, various papers published refer to lasers with different characteristics from diode lasers, from the articles of Christenburry in 1992 with argon lasers, to KTP,[7-9] CO_2,[10] or YAG.[11-16] We feel that these cannot be directly compared as their technical characteristics and the interaction with tissues are very different.

With our tests we have been able to demonstrate the findings seen in daily practice, along with observations that may give guidance on their causes.

The theory is correct. The more we concentrate the laser beam, the greater its effectiveness should be. This is achieved with silica-silica fibres (although an initial evaluation of the fibre we use showed that the real concentration of the beam, 19°, was lower than the theoretical value, which is supposed to be 20°). In practice, however, this degree of concentration hinders visual monitoring of the tip of the fibre. The focalization of energy probably induces a greater melting of bone tissue and creates a crust ahead of the light that should be guiding us, so it becomes obscured.

Furthermore, the concentration of the beam allows the creation of tunnels that closely fit the diameter of the fibre, but this implies 2 problems, among others. The first is that the fibre is often trapped in the tunnel we carve out and on occasions this obliges us to perform quite brusque traction manoeuvres to get it moving again and this, during surgery, means that we withdraw the fibre too much and it is necessary to repeat the manoeuvres to get it back in place. The second problem is the execution of very narrow tunnels which merge with great difficulty, so it is necessary to enlarge it through a very tight entranceway or to perform different parallel trajectories (with an appearance that might recall a shower head or a watering can) that we later have to bring together.

Silica-fluoropolymer fibres have a much larger theoretical output angle and diffuse the energy more (in the same way, we can see in the preliminary assessment that the real output angle was 28°, much less than the theoretical value of 40°). Nonetheless, this greater diffusion of energy also allows correct progression through the bone wall. By generating an orifice of greater diameter than the fibre, its ease of movement is greater, without the need to carry out forced manoeuvres. This provides for greater manual control with the required delicacy, as it is not necessary to remove the fibre from the bone at any time. It also seems that the lower concentration of power does not carbonize the bone so much and no crust is formed in front of the guide light, which is therefore visible at all times.

Parameters of Total Energy, Number of Impacts and Total Laser Exposure Time in Clinical Cases

Case	Total Energy, J	Impacts	Total Laser Time, s
1	373	80	37
2	723	156	73
3	528	107	61
4	623	142	59
5	714	155	71
6	667	148	66
7	640	147	64
8	389	82	42
9	475	95	50
10	596	134	59
Mean	558.97	120.9	56.99

By allowing the creation of a wider diameter orifice, it is also easier to enlarge this later without having to create multiple trajectories.

These characteristics allow us to apply our technique with less total energy expended in the operating area. This entails a more reduced thermal lesion and, in consequence, fewer scarring phenomena that might affect the success of the surgery.

What we have seen is that working in pulsed mode with a ratio of 500 ms of pulse to 500 ms of pause gives a more favourable result than working in continuous mode, as we had been doing previously,[1,2] a fact that had already been reported by other authors.[3,4] On the one hand, penetration into the bone is more effective and, on the other hand, the local generation of heat is much lower, thus minimizing the thermal lesion.

This way of working also reduces as far as possible the risk of the fibre's tefzel jacket igniting, although in our test this did not occur until after 27 s of firing in continuous mode, a totally exaggerated amount of time in surgery.

It is also significant to consider these differences when comparing studies published on techniques in which the results of laser use are compared. Not only are the different types of laser (KTP, YAG, diode) not comparable because of their different characteristics, but, as we have seen, it is also necessary to standardize the materials used with each type of laser to be able to compare different studies.

CONCLUSIONS

In our hands, silica-fluoropolymer-tefzel fibres have been shown to be more effective for the performance of transcanalicular DCR than those of silica-silica-polyamide.

Our tests indicate that their behaviour on organic tissue is better in terms of the degree of penetration, visibility and ease of manoeuvring within the bone tissue and their lower total energy requirement to complete the different manoeuvres.

The fibre's ignition risk is negligible in correct clinical use.

They also have the disadvantage that they cannot be resterilized because of it constituent materials.

Acknowledgments

Our thanks to Xavier Arcusa, INTERmedic engineer, for providing us with the guide materials and precision measurement instruments used, as well as for his collaboration in the study on the animal carcase.

REFERENCES

1. Sellares MT, Maeso J. Dacriocistorinostomia transcanalicular con láser diodo: Indicaciones y resultados. Annals d'Oftalmologia. 2006;14:152-8.
2. Maeso Riera J, Sellares Fabres MT. Dacriocistorrinostomía transcanalicular con láser diodo: variaciones técnicas y resultados. Acta Otorrinolaringol Esp. 2007;58:10-5.
3. Alañón Fernández FJ, Alañón Fernández MA, Martínez Fernández A, Cárdenas Lara M. Dacriocistorrinostomía transcanalicular con láser diodo. Resultados preliminares. Acta Otorrinolariongol Esp. 2004;55:171-6.
4. Alañón Fernández FJ, Alañón Fernández MA, Martínez Fernández A, Cárdenas Lara M. Dacriocistorrinostomía transcanalicular con láser diodo. Arch Soc Esp Oftalmol. 2004;79:325-30.
5. Plaza G, Beteré F. Efectividad de la dacriocistorinostomia transcanalicular en el tratamiento del lagrimeo del anciano. Mapfre Medicina. 2005;16:66-72.
6. Maeso Riera J, Sellarès Fabrés MT. Manual de tratamiento de la patología obstructiva lagrimal. Badalona: Área Científica Menarini-Gráficas del Maresme; 2006.
7. Muellner K, Bodner E, Mannor GE, et al. Endolacrimal laser assisted lacrimal surgery. Br J Ophthalmol. 2000;84:16-8.
8. Hofmann T, Lackner A, Muellner K, et al. Endolacrimal KTP laser-assisted dacryocystorhinostomy. Arch Otolaryngol Head Neck Surg. 2003;129:329-32.
9. Ressiniotis T, Voros GM, Kostakis VT, et al. Clinical outcome of endonasal KTP laser assisted dacryocystorhinostomy. BMC Ophthalmology. 2005;5:2.
10. Naraghi M, Tabatabaee Mohammadi SZ, Zolfkhani Z, Kashfi A. Endonasal endoscopic laser-assisted dacryocystorhinostomy. Acta Medica Iranica. 2002;40:140-5.
11. Sadiq SA, Ohrlich S, Jones NS, Downes RN. Endonasal laser dacryocystorhinostomy – Medium term results. Br J Ophthalmol. 1997;81: 1089-92.
12. Woo KI, Moon SH, Kim YD. Transcanalicular laser assisted revision of failed dacryocystorhinostomy. Ophthalmic Surg Lasers. 1998;29:451-5.
13. Kuchar A, Novak P, Pieh S, et al. Endoscopic laser recanalisation of presaccal canalicular obstruction. Br J Ophthalmol. 1999;83:443-7.
14. Bakri K, Jones NS, Downes R, Sadiq SA. Intraoperative fluorouracil in endonasal laser dacryocystorhinostomy. Arch Otolaryngol Head Nech Surg. 2003;129:233-5.
15. Morgan S, Austin M, Whittet H. The treatment of acute dacryocystitis using laser assisted endonasal dacryocystorhinostomy. Br J Ophthalmol. 2004;88: 139-41.
16. Hong JE, Hatton MP, Leib ML, Fay AM. Endocanalicular laser dacryocystorhinostomy. Ophthalmology. 2005;112:1629-33.