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ORIGINAL ARTICLE

Mechanical transnasal endoscopic dacryocystorhinostomy versus transcanalicular multidiode laser dacryocystorhinostomy: long-term results of a prospective study

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Abstract

The purpose of this study is to compare two dacryocystorhinostomy (DCR) techniques in epiphora treatment. This study is a prospective randomized trial. Twenty-nine patients presenting persistent epiphora due to primary acquired nasolacrimal duct obstruction (PANDO) were included in the study. Two groups each consisting of 15 eyes were formed. Mechanical transnasal endoscopic DCR (MTE-DCR) was applied to the first group, while transcanalicular dacryocystorhinostomy with multidiode laser (TCML-DCR) techniques is employed in the second group. Follow-up is conducted in the first day, first week, and first month of the dacryocystorhinostomy which is followed by 4-month follow-up period, and results were compared using statistical methods. The main outcome measures were the elimination of epiphora and unrestricted flow of irrigated saline to the nose. Seven patients were male, 22 were female, and the mean age was 39.3 ± 12.5 years. Mean follow-up times were 111.3 ± 10.5 months and 93 ± 2.9 months in group 1 and group 2, respectively. Complete resolution is achieved in group 1, whereas failures stemming from canalicular stenosis and fibrosis at osteotomy site are recorded in two cases in group 2. Occlusion occurred in the fifth month in both cases. Thus, long-term success rates were 100% in the first and 86.6% in the second group ($P = 0.483$). MTE-DCR is a strong substitute for external DCR. Although TCML-DCR shows promising results, it is far away from becoming the gold standard technique in epiphora treatment.

Keywords Dacryocystorhinostomy · Laser DCR · Multidiode laser · Nasolacrimal duct · NLDO

Background

Primary acquired nasolacrimal duct obstruction (PANDO) is one of the most common causes of epiphora. Besides its cosmetic ramifications negatively affecting the social life of the patient, PANDO also poses a functional problem that may require medical and surgical intervention for acute and chronic inflammatory conditions of the lacrimal sac [1]. The exact cause of PANDO mostly cannot be found, and the primary treatment of isolated nasolacrimal duct obstruction is usually dacryocystorhinostomy (DCR) surgery. In DCR surgery, surgeons drain lacrimal sac into the nasal cavity directly bypassing the obstruction site. After creating the new channel surgically, a silicone tube may be temporarily placed through this fistula to maintain patency in selected cases [2].

DCR can be carried out via external incision or endoscopic techniques such as mechanical transnasal endoscopic DCR and transcanalicular laser DCR. External DCR is currently the gold standard of lacrimal bypass surgery with a success rate of over 95% [3]. However, recent studies suggest that the success rate of mechanical transnasal endoscopic DCR is approaching to the level of external DCR. The advantages of endoscopic DCR are that it is less invasive, has a shorter operation time, preserves lacrimal pump function, has faster recovery, and avoids external scar. On the other hand, the initial cost of endoscopic DCR including equipment price can be high, and it requires a steep learning curve. Some authors prefer mechanical transnasal endoscopic DCR because it allows visualization of intranasal abnormalities such as deviated nasal septum and an enlarged middle turbinate preoperatively and additional nasal surgery if needed.

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Minimally invasive techniques like transcanalicular laser-assisted DCR have gained popularity recently. This procedure is performed with an incision-free technique that avoids visible scarring, requires shorter operating time, causes less bleeding, has quicker recovery time, and is easier to learn compared with other DCR methods [4, 5]. Yet, the reported overall success rate of laser-assisted DCR in relieving epiphora was shown to vary between 60 and 95% [6–8] which is a lower success rate than other DCR techniques. Nevertheless, some factors including appropriate patient selection, kind of laser, applying the laser DCR technique correctly, and efficient bone ablation have potential to augment the success rate. The aim of our study is to compare the long-term results of the standardized technique of mechanic endoscopic transnasal DCR with the standardized technique of transcanalicular DCR with multidiode laser technique.

Methods

Ethical approval

This prospectively randomized controlled study received approval from the Gazi University Ethical Committee (IRB#2008–366), and the tenets of the Declaration of Helsinki (2008) were followed. Informed consent was obtained from each subject at the time of the first clinical visit following explanation of the nature and possible consequences of the study and offering them an option of external DCR surgery.

Study population

Twenty-nine patients presenting constant watering eyes and were diagnosed with PANDO at oculoplastic and orbital surgery clinic of Gazi University Medical School were included in the study. Minimum sample size was calculated to be 25 persons in each group to achieve 95% significance level and 80% power—meaning the model will reject a false null hypothesis with 80% probability. This yields a power level of 65%; however, since we employed strict elimination criteria in recruitment, the power level is considered to be sufficient.

After taking a detailed medical history, all patients were put through detailed eye and endoscopic nasal examination. PANDO was confirmed primarily by syringing which is assisted by digital subtraction dacryocystography and lacrimal scintigraphy for certain cases. The obstruction site was at nasolacrimal duct in all patients.

All cases were informed about the surgical alternatives, and the patients who did not consent surgery with a skin incision were randomly assigned to one of two treatment groups following simple randomization procedures (computerized random numbers) using Statistical Package for the Social Sciences (SPSS). Mechanical transnasal endoscopic DCR (MTE-DCR) was applied in group 1, and transcanalicular DCR with multidiode laser (Multidiode S30 OFT, INTERmedic Arfran, Madrid, Spain) (TCML-DCR) was applied in the second group. Aside from the patient who had bilateral multidiode laser DCR, one eye from each patient was included in the study henceforth forming two groups of 15 eyes each. The patients were arranged in order for surgery according to date of first application. All surgeries were performed under general anesthesia by the same surgeon. Age, sex, epiphora duration, the timing of silicone tube removal, follow-up duration, and mitomycin C (Mit C) administration during surgery were prospectively evaluated in all cases.

Patients having epiphora caused by factors other than PANDO, upper lacrimal drainage system obstruction (punctal or canalicular block), lid pathology, history of nasolacrimal surgery, history of naso-orbital trauma, and serious nasal pathology that complicate endonasal surgery such as serious nasal pathology (advanced septal deviation, nasal polyps, concha bullosa, acute\chronic rhinitis\rhinosinusitis, etc.) and acute\chronic lacrimal system infection as well as those who cannot attend follow-up examination were excluded.

Surgical technique of mechanic endoscopic DCR

The nasal cavity was decongested preoperatively for 5 min using long cotton pledgets saturated with half-diluted 1:1000 epinephrine. Following proper operative site antisepsis, the lateral nasal wall and the middle turbinate mucosa were infiltrated with 2% lidocaine. After dilating the upper punctum with Bowman lacrimal probe, a 20-gauge blunt-tipped vitrectomy endoillumination probe was pushed forward through the upper canaliculus until a hard stop of the lacrimal bone was encountered and the transilluminated target area was viewed endoscopically (Fig. 1a). During surgery, 30^0 4 millimeter (mm) nasal endoscopes, an endoscopic DCR surgical kit, and a fiber optic light carrier (Storz endoscope instruments, Karl Storz, Germany) system were used. Nasal mucosa incisions were performed with a keratome ophthalmic knife in 2 mm behind and 6 mm in front of the illumination point (Fig. 1 b–c), and nasal mucosa was lifted over the bone with a Freer elevator (Fig. 1d). Yasargil micro scissor was used to cut nasal mucosa vertically, and a rectangular-shaped mucosal flap was created and excised with Hartmann forceps (Fig. 1e). At this stage, a discrete transilluminated target area under the bone was observed (Fig. 1f). Thereafter, a bone window was created with a Freer elevator by breaking the suture line between the lacrimal bone and frontalis process of the maxillary bone. The window was then enlarged with a 90^0 flat and a 45^0 inverse Smith-Kerrison forceps (Fig. 1g). At this point, the thick frontal protrusion of the maxillary bone located across the fundus of the lacrimal sac and the upper part of the nasolacrimal canal were especially removed. A hammer and

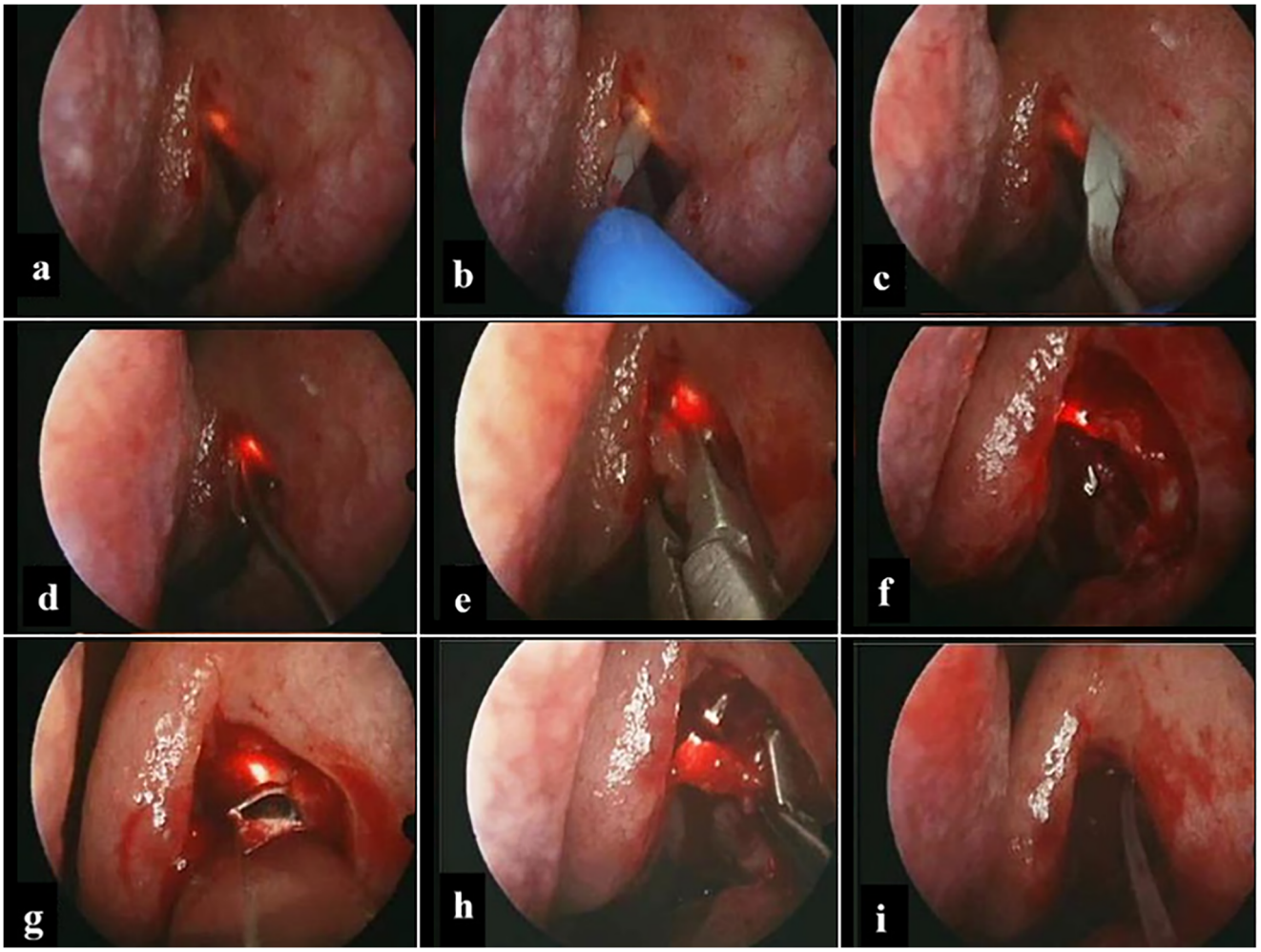

Fig. 1 Mechanic endoscopic dacryocystorhinostomy surgery procedure steps

chisel were used when necessary. The lacrimal sac was tented with Bowman probe, sac incision was made with keratome ophthalmic knife, and the sac wall was excised with Hartman forceps (Fig. 1h), and no antimetabolites were used. Finally, bicanalicular silicone intubation was performed, and the operation was ended (Fig. 1i). There were no intraoperative or postoperative complications.

Surgical technique of transcanalicular laser DCR

The nasal cavity was decongested preoperatively for 5 min using long cotton pledgets saturated with half-diluted 1:1000 epinephrine. After proper operative site antisepsis, the lateral nasal wall and the middle turbinate mucosa were infiltrated with 2% lidocaine. Then, the upper and lower canaliculi were dilated using Bowman lacrimal probe, and a rigid 30° nasal endoscope was inserted into the nose. Multidiode laser system was run on contact mode, and parameters were set at 10-W power and 500-ms pulse/500-ms pause for all patients. The radius of the multidiode laser fiber optic semirigid probe was 600 μm (Fig. 2). This probe was inserted into the lacrimal sac through the upper canaliculi until a hard stop of the lacrimal bone was encountered (Fig. 3a), and the transilluminated target area was viewed endoscopically from lateral and inferior to the middle turbinate (Fig. 3b). Nine hundred eighty-nanometer diode laser was applied with circular motions until the largest possible osteotomy was achieved. At this point, the middle turbinate was pushed from the midpoint with the aid of

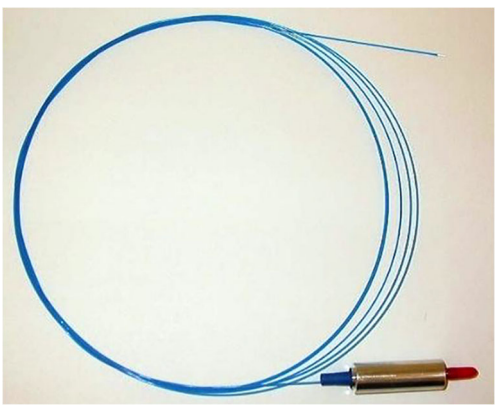

Fig. 2 Multidiode laser fiber optic probe

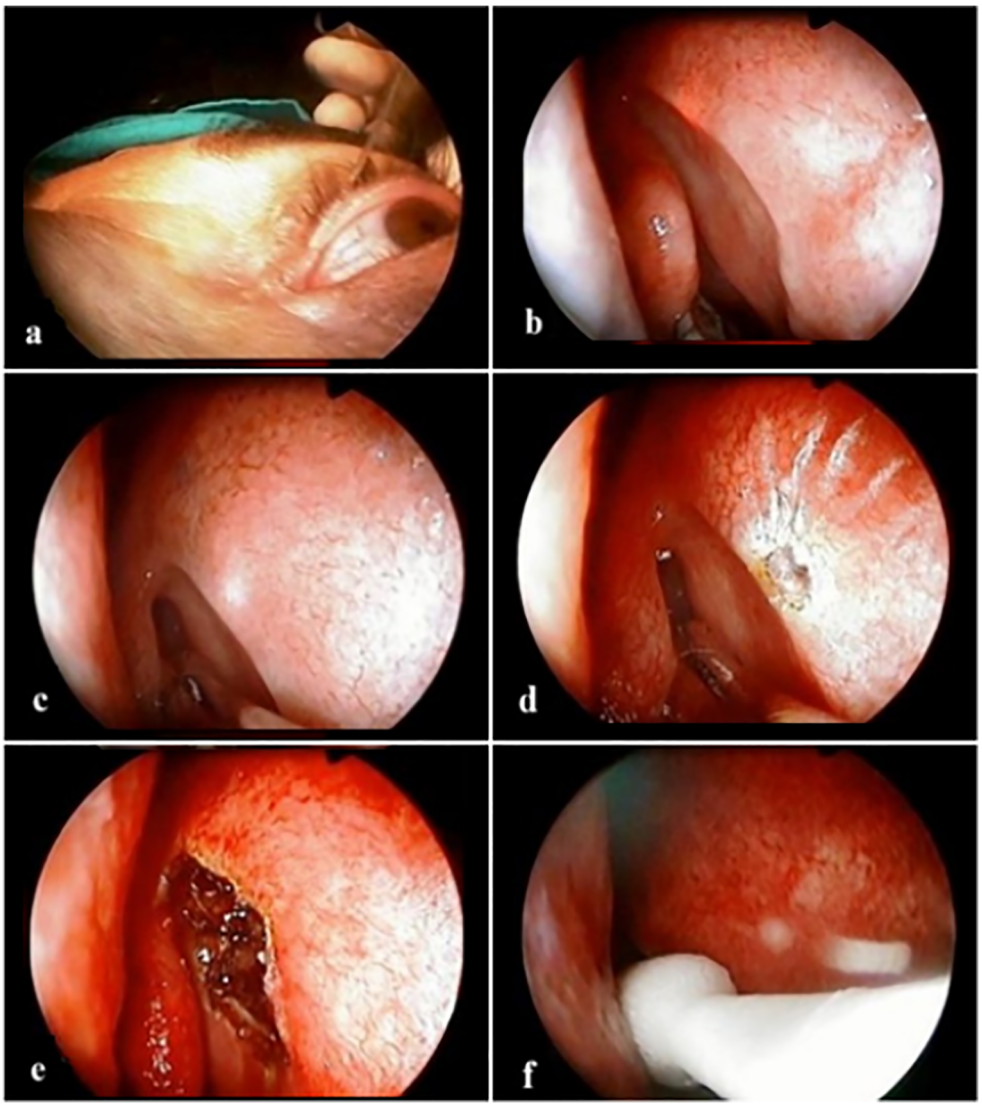

Fig. 3 Transcanalicular laser dacryocystorhinostomy surgery procedure steps

a periosteal elevator in order to protect it from laser beams and better visualize the osteotomy site. An osteotomy was initiated by laser pulses through contact with the nasal mucosa and lacrimal bone and continued until formation of the penetration, coagulation, and necrosis around the laser probe in the nasal mucosa (Fig. 3 c–d). Carbonized tissue was removed under endoscopic guidance. In some cases, laser beams were performed via lower punctum when needed. As a result of these steps, the diameter of the osteotomy area was expanded to approximately 8–10 mm (Fig. 3e). Nasolacrimal passage was intermittently irrigated using 0.9% sodium chloride (NaCl) from both upper and lower puncta throughout the operation. No significant intranasal laser damage was observed. At the end of the surgery, 0.4 mg\mL of Mit C was randomly applied to 6 eyes for 5 min within the osteotomy site (Fig. 3f).

In order to achieve randomization, the patients are numbered in ascending order according to their date of surgery, and only the even numbered patients were given Mit C. Bilateral multidiode was applied solely to the last patient (eyes numbered 14 and 15), and the patient was not given Mit C due to suspected drug allergy history. As a result of this randomization process, patients numbered 2, 4, 6, 8, 10, and 12 (6 eyes) were given Mit C, while patients numbered 1, 3, 5, 7, 9, 11, 13, and 14 (9 eyes) were not.

In all subjects, bicanalicular silicone intubation was performed, and the operation was terminated. There were neither intraoperative nor postoperative complications.

Postoperative care

In all cases, topical ofloxacin eye drop (Exocin, Allergan Ltd., Marlow International, Buckinghamshire, UK) 4 × 1, dexamethasone eye drop (Dekort, DEVA Ltd., Istanbul, Turkey) 4 × 1, mometasone furoate nasal spray (NASONEX Aqueous Nasal Spray, MSD Inc., Kenilworth, NJ, USA) 3 × 1, and isotonic saline nasal irrigation solution (Sinus Rinse Kit,

Abfen Farma, Ankara, Turkey) 4 × 1 were prescribed for 2 weeks starting from the first postoperative day. Nasal buffers were removed on day 1, and lacrimal passage was irrigated with 0.9% NaCl solution including gentamicin. Each patient was examined on day 1, week 1, month 1, and then for every 4 months during first year and annually afterwards. The silicone tubes were removed at 3 months postoperatively in the outpatient clinic for all cases.

Functional success was defined as the complete elimination of epiphora and the presence of patent ostium on lacrimal irrigation. Anatomical success was defined as the patent ostium on lacrimal irrigation despite continuing epiphora. Patients with persistent epiphora and closed ostium on lacrimal irrigation were defined as surgical failure.

Statistical analysis

Statistical analysis was performed using IBM SPSS Version 22.0 (IBM Corp., Armonk, NY, USA). Parameters are expressed as mean ± standard deviation and median (IQR, inter-quartile range). Fisher's exact test was used to analyze qualitative data, while Mann Whitney *U* test and independent sample t test were employed for quantitative data. 95% confidence interval and $P < 0.05$ significance level are considered threshold values for statistical significance.

Results

There were twenty-two females and 7 males in patient group. The mean age was 37.8 ± 12.2 years in MTE-DCR group and 40.8 ± 13.1 years in TCML-DCR group. The mean follow-up times were 111.3 ± 10.5 months and 93 ± 2.9 months in group 1 and group 2, respectively (Table 1). Complete anatomical and functional success is achieved in all cases in the MTE-DCR group, whereas surgical failures are recorded in 2 cases in the TCML-DCR group. Failure was due to canalicular stenosis in the first case and the fibrosis at the osteotomy site in the second one. Occlusion occurred in the fifth month in both cases henceforth bringing down long-term success rate for TCML-DCR group to 86.6% against 100% in MTE-DCR group ($P = 0.483$) (Fig. 4). Additionally, there was no statistically significant relationship between surgical success and Mit C usage in the TCML-DCR group (Table 2).

Discussion

Lacrimal system diseases have been a focus of interest for physicians since ancient times, and the chase for a remedy to epiphora has continued until today [9]. In this process, none of the several methods proposed to connect the lacrimal sac with the nose were accepted as the standard procedure due to their drawbacks until Toti [10] described the classical DCR technique in the 1900s. External DCR with Dupuy-Dutemps-Bourget's modified technique is currently being applied and is still considered the gold standard treatment for nasolacrimal duct obstructions with a success rate of above 90% [11].

As a matter of fact, surgical treatment of nasolacrimal duct obstructions was first attempted in 1893 by Caldwell [12] with a transnasal approach, yet deficiencies in imaging technology at that time resulted in unsuccessful operations with various complications. In the late twentieth century, the rapid developments in functional endoscopic sinus surgery let McDonogh and Meiring [13] introduce the first modern endoscopic DCR technique in 1989. Over the time, use of nasal forceps, radiofrequency units, and the development of endoscopic imaging methods have contributed to increasing success rates [14]. MTE-DCR technique has various advantages over external DCR such as less bleeding, shorter operation time, rapid recovery, and lower risk of Sump syndrome, thanks to inferiorly located rhinostomy site. In addition to

Table 1 Demographics and clinical parameters

Variables		MTE-DCR group ($n = 15$)	TCML-DCR Group ($n = 15$)	p value
Age (yr)		37.8 ± 12.2	40.8 ± 13.1	0.513 [a]
Gender (n, %)	Female	12 (80%)	10 (71.4%)	0.682 [b]
	Male	3 (20%)	4 (28.6%)	
Duration of symptoms (m)		12 (12)	12 (52)	0.683[c]
Follow-up (m)		111.3 ± 10.5	93 ± 2.9	*0.001* [a]

[a] Independent samples t test

[b] Fisher's exact test

[c] Mann-Whitney *U* test

MTE-DCR, mechanical transnasal endoscopic dacryocystorhinostomy; TCML-DCR, transcanalicular multidiode laser dacryocystorhinostomy; yr, years; n, number of eyes; m, month

Parameters are expressed as mean ± standard deviation and median (inter-quartile range)

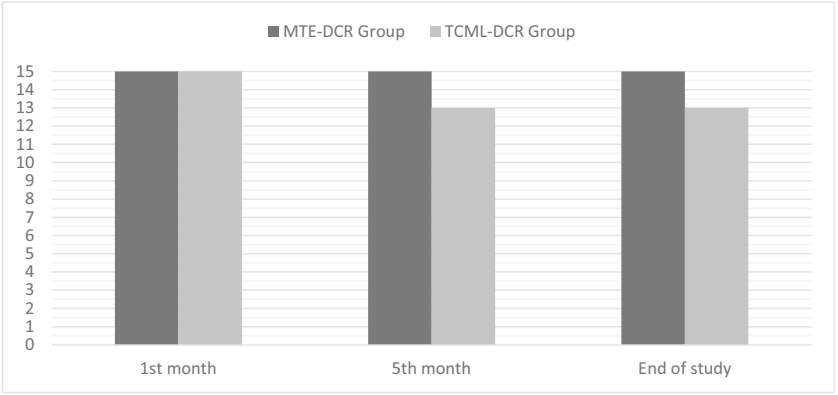

Fig. 4 Change in number of successful cases in groups over time

abovementioned advantages, MTE-DCR also preserves innocent neighbors such as medial canthal tendon and orbicular muscles as there is no skin incision, helps the surgeon to better navigate anatomic variations such as a deviated nasal septum or an enlarged middle turbinate that might lead to failure of the surgery, and has higher cosmetic complacency owing to absence of visible scars on patient's face [15].

Recent advent of surgical lasers revived interest in the use of transcanalicular laser-assisted DCR supported by endoscopic imaging for treating PANDO [16]. Obviously, the procedures with lower complications, higher success rates, shorter operation times, easier application, and better cosmetic results are preferred. In this context, the initial promise of surgical lasers led to introduction of holmium-doped yttrium aluminum garnet (Ho:YAG), argon, carbon dioxide (CO2), potassium-titanyl-phosphate (KTP) laser, and neodymium-doped yttrium aluminum garnet (Nd:YAG) laser [6, 17, 18]; nonetheless, diode laser was found to be the most suitable laser because of its certain properties. That is, the diode laser has 810–980 nm wavelength enabling both the highest efficiency with the lowest cost and higher absorption by hemoglobin during transcanalicular DCR [19]. On the other hand, although many studies show that endoscopic DCR assisted with laser ostium creation has less bleeding and a shorter recovery duration, it has a lower success rate than both MTE-DCR and external DCR.

A rigorous literature review points to a perplexing picture as the studies differ in terms of the technique of diode laser application, patient selection, laser application duration, age range, follow-up period, final osteotomy size, the experience of the surgeon, and so forth. Additionally, most of the studies have a short follow-up period, are retrospective in nature, and confer a reported success rate ranging from 60 to 95% [20, 21]. In summary, juxtaposition of the MTE-DCR and TCML-DCR techniques is a controversial topic. Addressing the abovementioned shortcomings, our study plays an important role by standardizing all the parameters affecting the final success rate with a fairly long follow-up duration and prospective character.

Table 2 Relationship between use of Mit C and surgical success rate in TCML-DCR group

	Successful (*n*)	Unsuccessful (*n*)	*p* value*
Mit C (+)	5	1	0.999
Mit C (−)	8	1	

*Fisher's exact test. Mit C, mitomycin C; n, number of eyes

The 100% success rate achieved by MTE-DCR in our study is above the upper range of 75–96% primary surgical success rate reported in the literature [22]. The eminence can be attributed to careful patient selection, accurate surgical indication, and effective use of the technique in the skilled hands. One of the basic rules that must be followed during lacrimal surgery for a positive outcome is to form a bone ostium of appropriate size and location [23]. It is shown that successful results can be achieved when the final osteotomy size is above 3 mm [24]. The osteotomy diameter can be larger than 10 mm in external DCR, 7 to 9 mm in MTE-DCR, and about 5 mm in transcanalicular laser DCR [25]. Following a successful DCR operation, the ostium patency is slightly reduced after the classical wound healing process. Yazici B et al. [26] showed in their study with 41 external DCR cases that there is no significant correlation between the final ostium size at 6 months and preoperative osteotomy diameter. In the aforementioned study, the osteotomy regressed to 3.8 mm (1.6–6.5) from its initial value of 13.5 mm (11.5–16.3) at the end of the study. These findings show that scar formation caused by inflammatory response secondary to surgical trauma may show personal differences which in turn affect surgical success. Therefore, the largest possible osteotomy must be created during DCR operation.

In TCML-DCR, besides the osteotomy size, selected laser mode, maximum applied laser power, and the structure of the fiber optic probe are also important. Literature shows that if the laser power is less than 7 W, the ablation will fail, whereas in case it exceeds 15 W, it may cause carbonization and lateral tissue damage. Thus, a 7 to 15 W power range can be considered as the appropriate dose [27]. In our study, 10 W power level was used for all cases.

The overheating of tissues, another important problem in laser DCR, cannot be prevented despite the special design of high technology fiber optic probes. An ex vivo study on live animal bones concluded that a temperature of 80 °C with an energy level of 1000 J can be safely used for a successful laser DCR [28]. In vivo applications, on the other hand, contradict those findings. For example, in another study, 250°C was reached when 300 J energy is used [29]. As a result, reckless use of laser may cause upper lacrimal system burn and stenosis which can only be treated by additional complicated surgeries such as conjunctivodacryocystorhinostomy with lacrimal canalicular bypass tube implantation.

Furthermore, fistula formation between lacrimal canaliculi and skin, false passage formation, damage to the common canaliculus, orbital cellulitis, and even complete vision loss may develop when the technique is not applied properly [30]. Carbonization of the nasal mucosa due to intense laser applications may also cause failure. To avoid tissue burns, extensive irrigation of the entire operation site should be routinely performed in order to reduce the disproportionate inflammatory response and achieve wound stabilization [31]. Actually, we encountered the carbonization problem in all TCML-DCR cases, yet we tried to prevent ostium closure by cleaning the burned tissues with both mechanical debridement and irrigation and protecting the middle turbinate from the synechiae. Postoperative care is also very important in surgical success, especially the regular use of nasal steroids and proper application of nasal irrigation solution.

In fact, one of the patients who failed in the multidiode group had ostium fibrosis and the other one had canalicular stenosis. These results show that laser DCR technique can become complicated even in experienced hands under ideal conditions. Hence, the golden rules for a successful laser DCR are gaining the know-how of where to make the shoot and how to make it, getting experience on the device, preparing the fiber optic probe properly, and operating the endoscope carefully. Additionally, it is emphasized in the literature that laser DCR technique should not be selected in complicated cases with naso-orbital trauma, revision surgeries, suspicion of lacrimal sac tumor, canalicular problems, and severe nasal pathologies [32].

In some cases, the ostium patency after DCR operation can be completely closed with the excess granulation tissue, especially in 4–6th months following the operation. In line with this knowledge, the obstruction of lacrimal passage was observed in the 5th month postoperatively in our cases. Inspired by glaucoma and pterygium surgeries, it has been suggested that preoperative use of Mit C, an antimetabolite, may be beneficial in repressing the formation of granulation tissue. Mit C, like other antimetabolites, acts by inhibiting DNA\RNA replication, cell division, protein synthesis, and fibroblast proliferation. Some of the studies in the literature suggest that Mit C is effective in DCR, while others argue that Mit C application prevents additional scar formation yet does not affect the surgical success [33, 34]. In our study, we did not need to use Mit C in MTE-DCR group as we were able to reach adequate ostium size with smooth and fresh mucosal incisions. In TCML-DCR group, although we randomly tried Mit C in some cases with the hope to increase the success by preventing the potential side effect of carbonization, there was no statistically significant difference.

Conclusions

Our study shed light on some important issues such as long-term results of the TCML-DCR, a new alternative in lacrimal surgery, and MTE-DCR. Mechanical transnasal endoscopic DCR has once again proved to be a powerful alternative to external DCR. TCML-DCR shows promising results; however, there are still some obstacles to tackle in order to become an alternative treatment in PANDO. The ideal scenario is that the laser DCR surgeries should be done by oculoplastic surgeons experienced in external DCR who also have knowledge and experience in endoscopic DCR. Otherwise, these surgeries may result in unsuccessful surgeries complicated by fibrosis of the ostium, upper lacrimal system stenosis, and nasal synechiae.

Meeting presentation and other information This study is a doctoral dissertation and was presented in 46th Turkish Ophthalmology Society National Congress (17–21 October 2012, Antalya, Turkey) as an oral presentation.

Authors' contributions HTA, OK: study design, critical revision; HTA: data acquisition, interpretation, article writing;
OK: performing surgeries, supervision. All the authors have read and approved the final manuscript.

Data availability The datasets generated and/or analyzed during the present study are not publicly available (obtained from Gazi University Hospital, Ankara repository) but are available from the corresponding author upon reasonable request.

Compliance with ethical standards

Conflict of interest The authors declare that they have no competing interests.

Ethical approval This prospectively randomized controlled study received approval from the Gazi University Ethical Committee (IRB#2008–366), and the tenets of the Declaration of Helsinki (2008) were followed.

Informed consent Written informed consent was obtained from each patient before his/her participation.

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