Carbon Dioxide Laser Transconjunctival Lower Blepharoplasty: An Objective and Quantitative Comparison to Monopolar Electrosurgery

Chia-Fang Chen, MD
Shih-Hsuan Mao, MD
Cheng-I Yen, MD
Shih-Yi Yang, MD
Yen-Chang Hsiao, MD
Jui-Yung Yang, MD
Shu-Yin Chang, MD
Shiow-Shuh Chuang, MD
Hung-Chang Chen, MD

Taoyuan, Taiwan

Background: The ability to simultaneously cut and perform hemostasis with low lateral thermal injury makes carbon dioxide laser a useful tool in blepharoplasty. Monopolar electrosurgery is another commonly used cutting tool that improves the quality of hemostasis and cutting speed. This study aimed to objectively and quantitatively assess the intraoperative and postoperative outcomes of transconjunctival lower blepharoplasty using either a carbon dioxide laser or monopolar electrosurgery.

Methods: Between August of 2018 and March of 2021, 78 patients who underwent transconjunctival lower blepharoplasty were assigned randomly to the carbon dioxide laser group or the monopolar electrosurgery group. Patient-related parameters were recorded. Periorbital bruises were assessed objectively and quantitatively using the ecchymosis evaluation score. Analyses were performed using the independent sample *t* test, the Mann-Whitney *U* test, the chi-square test, and the Fisher exact test.

Results: Sex, age, local anesthesia injection volume, and fat removal volume were not different between the groups. Patients' subjective intraoperative heat sensation was significantly higher in the monopolar electrosurgery group than in the carbon dioxide laser group. The carbon dioxide laser group had a significantly lower incidence of postoperative chemosis than the monopolar electrosurgery group. All patients had uncomplicated wound healing, except three (7.89%) patients in the monopolar electrosurgery group who developed conjunctival granuloma. Operation time, intraoperative pain sensation, intraoperative blood pressure, postoperative ecchymosis, conjunctivitis, and patients' aesthetic satisfaction did not differ between the groups.

Conclusion: The authors' findings revealed that carbon dioxide laser is a useful technique for reducing intraoperative heat sensation and postoperative chemosis and may prevent conjunctival wound complications. *(Plast. Reconstr. Surg.* 152: 747, 2023.)

CLINICAL QUESTION/LEVEL OF EVIDENCE: Therapeutic, II.

In 1973, Tessier[1] developed transconjunctival lower blepharoplasty. Over decades, this method has been proven to be feasible and safe for lower eyelid rejuvenation.[2]

Kumar Patel[3] of Bell Labs developed the carbon dioxide laser in 1964. Carbon dioxide laser produces a beam of infrared light with a wavelength 10.6 μm, which has an extremely high absorption rate in water.[4] Because soft tissue is composed of 90% water, carbon dioxide laser has been useful in several soft-tissue operations. It works by sealing off the blood and lymphatic vessels while it cuts, minimizing intraoperative bleeding and providing a clearer operative field. Energy is conducted and absorbed by the target

From the Department of Plastic and Reconstructive Surgery, Chang Gung Memorial Hospital, College of Medicine, Chang Gung University.
Received for publication July 21, 2021; accepted September 1, 2022.

DOI: 10.1097/PRS.0000000000010255

Disclosure statements are at the end of this article, following the correspondence information.

Related digital media are available in the full-text version of the article on www.PRSJournal.com.

site quickly, creating only very narrow zones of thermal necrosis (approximately ≤500 μm).[5] The ability to simultaneously cut and to perform hemostasis with low lateral thermal injury makes carbon dioxide laser a useful tool in soft-tissue surgery.

Baker et al.[6] first applied carbon dioxide laser in blepharoplasty. They found that compared with the conventional cold steel scalpel method, carbon dioxide laser reduced intraoperative hemorrhage, which minimized postoperative ecchymosis and tissue edema. Multiple studies have been conducted to investigate the feasibility of carbon dioxide laser in periorbital aesthetic operations, reporting controversial results. One study that compared carbon dioxide laser with cold steel and electrocautery device showed a significant decrease in interoperative bleeding and operation time, and a significant improvement of postoperative swelling and bruising in the carbon dioxide laser group.[7] Glassberg et al.[8] and Morrow and Morrow[9] reported similar findings in their studies and concluded that carbon dioxide laser was better in controlling intraoperative bleeding, but both carbon dioxide laser and cold steel methods had similar good aesthetic outcomes. However, Mittelman and Apfelberg[10] reported that carbon dioxide laser had no clear benefit in blepharoplasty and that it increased the risk of negative safety factors or accidents in their study. Another study found that the Colorado needle tip with electrosurgery provides benefits comparable to those of carbon dioxide laser in blepharoplasty, but at a lesser cost and with shorter intraoperative times.[11] However, the cost could be equal to or less than monopolar cautery, depending on the longevity of the laser. Monopolar cautery can have a significantly higher cost per case, which can increase over time.

Electrosurgery is another commonly used cutting tool in blepharoplasty, which improves the quality of hemostasis and cutting speed. However, it can also cause complications, particularly when using monopolar energy, which accounts for 53% of all electrosurgery-related side effects.[12] During monopolar electrosurgery, inadvertent harm and delayed injury to the surrounding tissue can occur because of the lateral spread of thermal energy.[13] In contrast, there is almost no lateral thermal damage inflicted to adjacent tissues during carbon dioxide laser blepharoplasty.[14]

Although many prior studies have sought to compare the efficacy of carbon dioxide laser with that of other surgical instruments in periorbital operations, the number of cases included was small, and the results lack intraoperative outcomes. The goal of this study was to objectively and quantitatively assess the intraoperative and postoperative outcomes (convalescence) of transconjunctival lower blepharoplasty using either a carbon dioxide laser or monopolar electrosurgery.

PATIENTS AND METHODS

This retrospective study was approved by the institutional review board of Chang Gung Memorial Hospital. All participants signed a written consent form that included a detailed explanation of the risks and benefits of the procedures. We included all patients who had undergone transconjunctival lower blepharoplasty performed by the same surgeon in our hospital from August of 2018 to March of 2021.

When performing transconjunctival eye bag removal, patients were randomly assigned into two groups—those who underwent the carbon dioxide laser approach by Ultrapulse (Lumenis, Inc., Santa Clara, CA) were included in the carbon dioxide laser group, whereas those who underwent monopolar electrosurgery using a model 300 electrosurgical unit (Yueh Sheng Electronic Industrial Co., Ltd.) with a fine electrode tip (Colorado microdissection needle; Stryker, Inc., Kalamazoo, MI) were included in the monopolar electrosurgery group. An impenetrable scleral shield was always used to protect the patient's eyes during the procedure; therefore, patients were unaware of which instrument was being used.

Surgical Technique

For transconjunctival eye bag removal, in the carbon dioxide laser group, all cutting, tissue dissection, and fat removal were performed with 5 W of energy in the continuous mode and a 0.2-mm diameter spot size. In the monopolar electrosurgery group, all procedures were performed with cutting and coagulation at 15 W and 13 W, respectively.

The conjunctiva was infused with lidocaine (2% lidocaine with 1:100,000 epinephrine) and evaluated after at least 7 minutes for the onset of the epinephrine effect. A 15-mm incision was made approximately 5 mm inferior to the lower border of the tarsus using either monopolar electrosurgery or carbon dioxide laser. During the carbon dioxide laser transconjunctival incision and lower lid retractor release, there was essentially no bleeding; in contrast, there was minimal to substantial bleeding in the monopolar electrosurgery group. The orbital retaining ligament and

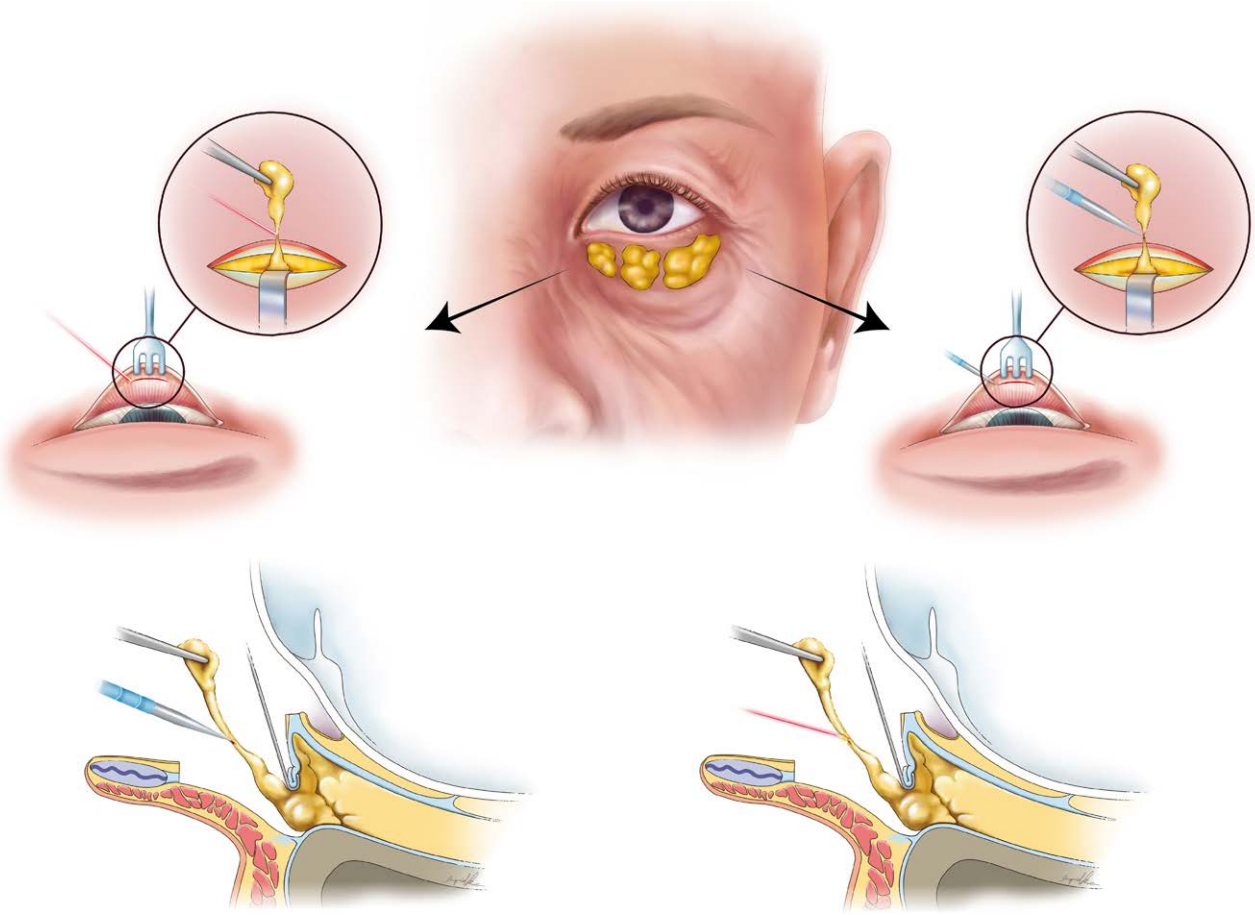

Fig. 1. Transconjunctival eye bag removal assisted by carbon dioxide laser (*left*) and monopolar electrosurgery (*right*).

tear trough ligament were bluntly released with a cotton tip after dissecting the preseptal region down to the arcus marginalis. Three excisions were made along the medial, central, and lateral compartments of the orbital septum. Extrusion of orbital fat while applying slight pressure to the orbit was used to determine the amount of fat removed. Excessive fat removal was not necessary. The conjunctival wound was not repaired (Fig. 1). [**See Video (online)**, which demonstrates carbon dioxide laser transconjunctival eye bag removal.]

Parameters

Data on demographics including age, sex, total removed fat volume, and injected lidocaine volume were recorded. Patient-reported intraoperative heat and pain during the transconjunctival approach were recorded using a visual analogue scale (VAS) ranging from 0 to 10. Intraoperative blood pressure was also recorded. The operation time was recorded to determine which strategy was more convenient for surgeons. To achieve a more accurate evaluation of postoperative periorbital bruises, we developed an ecchymosis evaluation score. Patients who had no bruises at all were assigned a score of 0, those with minor yellow and green bruises were assigned a score of 1, and those who had dark purple bruises were assigned a score of 2 to 4 based on their severity (Table 1). The ecchymosis scores of all 78 patients were evaluated by six qualified plastic surgeons and one senior nurse using photographs taken on postoperative day 7. We also recorded

Table 1. Ecchymosis Evaluation Score[a]

0	1	2	3	4
No bruising	Yellow/green	Yellow/green with mild dark purple bruise	Yellow/green with moderate dark purple bruise	Yellow/green with severe dark purple bruise

[a]Patients who had no bruises at all were assigned a score of 0, those with minor yellow and green bruises were assigned a score of 1, and those who had dark purple bruises were assigned a score of 2–4 based on their severity.

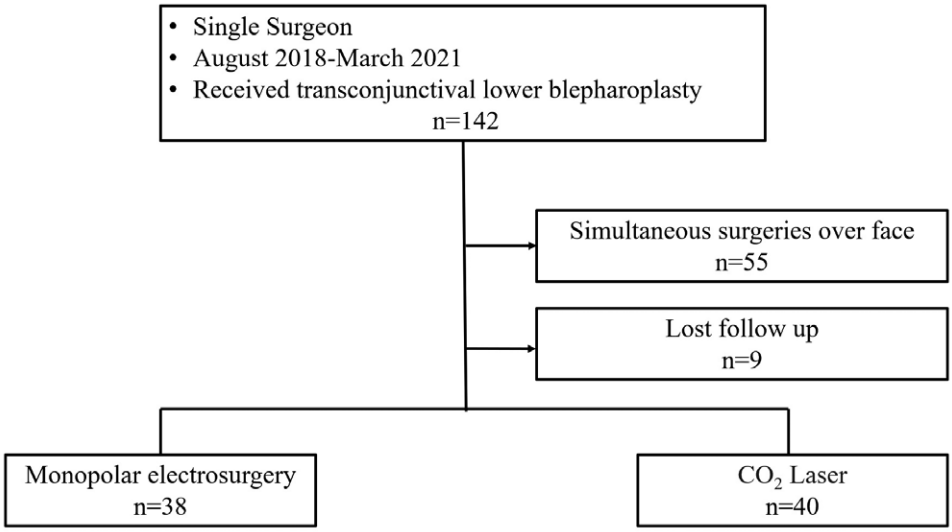

Fig. 2. Study flow diagram. A total of 78 patients were enrolled and assigned randomly to the carbon dioxide laser group (40 patients) or the monopolar electrosurgery group (38 patients). Exclusion criteria included receiving simultaneous surgery over the face ($n = 55$) or patient failure to present at follow-up ($n = 9$).

the incidence of chemosis and comorbidities to better compare the risk of lateral thermal injury by the two cutting tools on postoperative day 7. The patients' satisfaction scores were rated by themselves using a VAS (ranging from 0 to 100) 2 months postoperatively. All complications were documented.

Statistical Analysis

All data are reported as mean ± SD except for the removed fat volume, injected lidocaine volume, intraoperative heat sensation, and intraoperative pain sensation analyzed using the Mann-Whitney *U* test, for which the result was presented as the median with interquartile range (IQR). Analyses were performed with the help of IBM SPSS Statistics Version 25 using the independent sample *t* test, Mann-Whitney *U* test, Fisher exact test, and the chi-square test. Statistical significance was set at $P < 0.05$.

RESULTS

A total of 142 patients underwent transconjunctival lower blepharoplasty between August of 2018 and March of 2021. We excluded patients who underwent simultaneous operations of the face ($n = 55$) and those who were lost to follow-up ($n = 9$). Finally, a total of 78 patients were enrolled and assigned randomly to the carbon dioxide laser group ($n = 40$) or the monopolar electrosurgery group ($n = 38$) (Fig. 2).

Data on demographics, including sex, age, local anesthesia injection volume, and fat removal volume, were analyzed using the independent sample *t* test, Mann-Whitney *U* test, and chi-square test. The results showed no difference in these parameters between the groups, indicating that the surgical tool was the only variable (Table 2).

Intraoperative Outcomes

The total operation time did not differ between the carbon dioxide laser group (148.41 ± 20.80 minutes) and the monopolar electrosurgery

Table 2. Patient Characteristics of Carbon Dioxide Laser and Monopolar Electrosurgery Groups

	Electrosurgery	Laser	*P*[a]
No.	38	40	
Mean age ± SD, yr[b]	53.80 ± 10.4	55.12 ± 8.8	0.27
Sex[c]			
M	7	14	0.10
F	31	26	
Removed fat volume[d]			0.25
Median	0.96	1.11	
IQR	0.60–1.42	0.84–1.80	
Injected lidocaine volume[d]			0.93
Median	0.70	0.70	
IQR	0.54–0.85	0.60–0.83	

M, male; F, female.
[a] $P < 0.05$ indicates statistical significance.
[b] Independent sample *t* test.
[c] χ^2 test.
[d] Mann-Whitney *U* test.

Table 3. Intraoperative Outcomes

	Electrosurgery	Laser	P[a]
No.	38	40	
Mean operation time ± SD, min[b]	146.92 ± 26.10	148.41 ± 20.80	0.39
Intraoperative heat[c]			0.01
Median	3.00	2.00	
IQR	2.00–4.00	0.00–2.25	
Intraoperative pain[c]			0.75
Median	3.00	3.00	
IQR	2.00–5.00	2.00–4.00	
Mean intraoperative blood pressure ± SD, mmHg	140.54 ± 23.43	128.33 ± 24.83	0.15

[a]$P < 0.05$ is statistically significant.
[b]Independent sample *t* test.
[c]Mann-Whitney *U* test.

Table 4. Postoperative (Convalescence) Outcomes

	Electrosurgery	Laser	P[a]
No.	38	40	
Chemosis[c]			0.04
No.	12	5	
Incidence, %	31.60	12.50	
Conjunctivitis[c]			0.69
No.	8	7	
Incidence, %	21.05	17.50	
Mean ecchymosis ± SD[b]	2.36 ± 0.97	2.03 ± 1.11	0.16
Mean patients aesthetic satisfaction ± SD[b]	90.9 ± 7.1	89.2 ± 9.5	0.56
Conjunctival wound granuloma[d]			0.11
No.	3	0	
Incidence, %	7.89	0	

[a]$P < 0.05$ indicates statistical significance.
[b]Independent sample *t* test.
[c]χ^2 test.
[d]Fisher exact test.

group (146.92 ± 26.10 minutes). The carbon dioxide laser group experienced significantly less heat sensation during surgery than the monopolar electrosurgery group. Patients' subjective intraoperative heat sensation (VAS ranging from 0 to 10) was 3.00 (IQR, 2.00 to 4.00) in the monopolar electrosurgery group and 2.00 (IQR, 0.00 to 2.25) in the carbon dioxide laser group ($P = 0.01$). Patients' subjective intraoperative pain sensation (VAS ranging from 0 to 10) was 3.00 (IQR, 2.00 to 5.00) in the monopolar electrosurgery group and 3.00 (IQR, 2.00 to 4.00) in the carbon dioxide laser group, and there was no statistical significance ($P = 0.75$). The difference in intraoperative blood pressure was not statistically significant between the monopolar electrosurgery and carbon dioxide laser groups (140.54 ± 23.43 mmHg versus 128.33 ± 24.83 mmHg), but there was a trend toward higher blood pressure in the monopolar electrosurgery group (Table 3).

Postoperative Outcomes

Patients who underwent monopolar electrosurgery were assigned a higher ecchymosis score than those who underwent carbon dioxide laser (2.36 ± 0.97 versus 2.03 ± 1.11). Nevertheless, the difference was small and not statistically significant. The carbon dioxide laser group had a significantly lower incidence of chemosis (12.5%) than the monopolar electrosurgery group (31.6%; $P = 0.04$). There was a statistically significant difference in the incidence of conjunctivitis between the monopolar electrosurgery and carbon dioxide laser groups (21.05% versus 17.50%). [**See Figure, Supplemental Digital Content 1**, which shows patients' photographs from the preoperative stage (*above*) and postoperative day 7 (*below*) in the carbon dioxide laser group, ***http://links.lww.com/PRS/G98***. **See Figure, Supplemental Digital Content 2**, which shows patients' photographs from the preoperative stage (*above*) and postoperative day 7 (*below*) in the monopolar electrosurgery group, ***http://links.lww.com/PRS/G99***.]

The overall judgment of the appearance of the lower eyelid was reported by patients at 2 months postoperatively. The aesthetic satisfaction in both groups was high—89.2 (range, 70 to 100) in the carbon dioxide laser group and 90.9 (range, 70 to 100) in the electrosurgery group ($P = 0.56$). With the exception of three patients (7.89%) in the monopolar electrosurgery group who developed conjunctival granuloma, which was later cured by simple surgical removal, all patients had uncomplicated conjunctival wound healing (Table 4).

DISCUSSION

To our knowledge, this is the largest study (78 cases) to compare the intraoperative and postoperative outcomes of carbon dioxide laser and monopolar electrosurgery in transconjunctival lower blepharoplasty. Our findings revealed no difference in patients' aesthetic satisfaction at 2 months postoperatively between both techniques, which is consistent with the findings of previous studies.[8–10] Because long-term follow-up showed no difference between carbon dioxide laser and the other surgical tools, the focus of this study was on intraoperative and short-term postoperative (convalescence) outcomes.

During transconjunctival lower blepharoplasty, patients may experience pain and heat in the surgical area, which is a major concern for surgeons. Intraoperative pain and heat not only irritated patients but also raised their blood pressures, potentially increasing intraoperative bleeding. We evaluated the patients' subjective intraoperative pain and heat sensation and found that both groups experienced similar intraoperative pain, and the carbon dioxide laser group experienced significantly reduced intraoperative heat sensation. All layers of skin have sensory receptors. Temperature (thermoreceptors) and pain (nociceptors) are two different types of skin signals. Nociceptors transmit signal only when the body has reached a point of tissue damage. In this study, patients' subjective intraoperative heat sensation was significantly higher in the electrocautery group, which might indicate a potential risk of lateral thermal injury. However, the temperature of the heat source might not always be high enough to cause pain. Therefore, patients' subjective intraoperative pain sensation was not considered significantly high in the electrocautery group. Although the result of intraoperative blood pressure failed to reach a statistically significant level between the groups, there was a trend toward higher blood pressure in the monopolar electrosurgery group. Our results also indicate that patients may feel more comfortable during carbon dioxide laser transconjunctival blepharoplasty.

To evaluate which approach is more convenient for surgeons, the operation time in each approach was recorded. Although many prior studies have shown that the carbon dioxide laser approach reduces the operation time,[7–9] our results showed that there is no difference in operation time between the two methods. More-complicated sterile preparation and laser reflection protection may increase surgery time. Reflected carbon dioxide laser energy on operative field materials poses risks to patients and operating room personnel.[15] All surgical instruments with polished surfaces and patients exposed to surgical fields should be covered with damp gauze to prevent such damage. Laser-safe instruments that are anodized can also be used in addition to wrapping them in wet gauze. The large handpiece of carbon dioxide laser is not as easy to handle as that of monopolar electrosurgery, which could also increase the surgery time. Despite these unfavorable factors, the operation time in the carbon dioxide laser group was comparable to that in the monopolar electrosurgery group.

Ecchymosis served as a representative measure of intraoperative bleeding. Because of the excellent ability of simultaneous cutting and hemostasis, carbon dioxide laser–assisted blepharoplasty has been reported to significantly decrease intraoperative bleeding and reduce the incidence of postoperative bruising. Patients can return to normal social activity sooner, with less postoperative ecchymosis. In this study, we developed an ecchymosis score and evaluated postoperative periorbital bruising on postoperative day 7. Although the average ecchymosis score was higher in the monopolar electrosurgery group than in the carbon dioxide laser group, there was no statistically significant difference, indicating that the severity of ecchymosis was similar between the groups. The carbon dioxide laser and monopolar electrosurgery groups had similar and high levels of aesthetic satisfaction, indicating that both methods can achieve good cosmetic results.

Lateral thermal injury during surgery may lead to swelling and inflammation of the bulbar conjunctiva and cause chemosis and conjunctivitis, which are another two common side effects during convalescence. We compared the incidence of chemosis and conjunctivitis between the groups on postoperative day 7. Although the carbon dioxide laser group had a lower incidence of conjunctivitis than the monopolar electrosurgery group, the difference was not statistically significant. Both groups shared a similar probability to develop conjunctivitis. There was a significant decrease in the incidence of chemosis in the carbon dioxide laser group compared with that in the monopolar electrosurgery group. Our results echo those of one prior study, which concluded that no lateral thermal damage was inflicted to adjacent tissues during carbon dioxide laser blepharoplasty.[14] No prior studies have compared the extent to which thermal damage travels with a Colorado tip or a carbon dioxide laser. Nechay et al. reported that the heat spread exceeded 2 cm laterally along the mesoappendix when the application time exceeded 3 seconds during a monopolar electrosurgery–assisted appendectomy.[13] David and Abergel monitored the conjunctival temperature during carbon dioxide laser incision of the upper eyelids and revealed an average temperature increase of 0.5°C.[14] Although the temperature increase did not result in lateral thermal injury, it is possible that the heat could spread from the upper eyelid to the conjunctiva during carbon dioxide laser blepharoplasty. Our observations suggest that the heat could spread much farther in monopolar electrosurgery.

Mullins et al. reported that conjunctival granulomas developed in eight of 400 patients (2%) who underwent transconjunctival blepharoplasty.[16] However, they did not mention the instrument used during the operation. In this study, 142 patients underwent transconjunctival lower blepharoplasty, and three of 142 patients (2.1%) developed conjunctival granulomas. The incidence of conjunctival granuloma in this study was not specifically higher than that reported in a previous study. However, all three patients developed conjunctival granuloma in the monopolar electrosurgery group [three of 38 (7.89%)], whereas none of the patients in the carbon dioxide laser group developed postoperative granuloma. Conjunctival wound granulomas may represent another side effect of lateral thermal injury during a transconjunctival incision. Our results suggest performing routine primary wound closure after monopolar electrosurgical transconjunctival blepharoplasty to prevent conjunctival wound granuloma.

CONCLUSIONS

We conducted an objective and quantitative evaluation to compare carbon dioxide laser and monopolar electrosurgery in transconjunctival lower blepharoplasty. Our findings revealed that carbon dioxide laser is a useful technique for reducing intraoperative heat sensation and postoperative chemosis and may prevent conjunctival wound complications. Operation time, intraoperative pain, postoperative ecchymosis, and conjunctivitis were similar between the two surgical tools.

Hung-Chang Chen, MD
Department of Plastic and Reconstructive Surgery
Linkuo Chang Gung Memorial Hospital
5, Fu-Hsin Street, Kwei-Shan
Taoyuan 333, Taiwan
firepigtw@gmail.com

DISCLOSURE

The authors have no financial interest in any of the products, devices, or drugs mentioned in this article. No funding was received for this article.

PATIENT CONSENT

Patients provided written informed consent for the use of their images.

REFERENCES

1. Tessier P. The conjunctival approach to the orbital floor and maxilla in congenital malformation and trauma. *J Maxillofac Surg.* 1973;1:3–8.
2. Sullivan PK, Drolet BC. Extended lower lid blepharoplasty for eyelid and midface rejuvenation. *Plast Reconstr Surg.* 2013;132:1093–1101.
3. Patel CKN. Continuous-wave laser action on vibrational-rotational transitions of CO2. *Phys Rev.* 1964;136:A1187–A1193.
4. Sharp MC. Laser processing of medical devices. In: Meglinski I, ed. *Biophotonics for Medical Applications.* Boston: Woodhead Publishing; 2015:79–98.
5. Sawisch TJ. Oral surgery for the general practitioner. In: Convissar RA, ed. *Principles and Practice of Laser Dentistry.* St. Louis: Mosby; 2011:93–113.
6. Baker SS, Muenzler WS, Small RG, Leonard JE. Carbon dioxide laser blepharoplasty. *Ophthalmology* 1984;91:238–244.
7. David LM, Sanders G. CO2 laser blepharoplasty: a comparison to cold steel and electrocautery. *J Dermatol Surg Oncol.* 1987;13:110–114.
8. Glassberg E, Babapour R, Lask G. Current trends in laser blepharoplasty. Results of a survey. *Dermatol Surg.* 1995;21:1060–1063.
9. Morrow DM, Morrow LB. CO2 laser blepharoplasty. A comparison with cold-steel surgery. *J Dermatol Surg Oncol.* 1992;18:307–313.
10. Mittelman H, Apfelberg DB. Carbon dioxide laser blepharoplasty—advantages and disadvantages. *Ann Plast Surg.* 1990;24:1–6.
11. Rokhsar CK, Ciocon DH, Detweiler S, Fitzpatrick RE. The short pulse carbon dioxide laser versus the Colorado needle tip with electrocautery for upper and lower eyelid blepharoplasty. *Lasers Surg Med.* 2008;40:159–164.
12. Overbey DM, Townsend NT, Chapman BC, et al. Surgical energy-based device injuries and fatalities reported to the Food and Drug Administration. *J Am Coll Surg.* 2015;221:197–205.e1.
13. Nechay TV, Titkova SM, Anurov MV, et al. Thermal effects of monopolar electrosurgery detected by real-time infrared thermography: an experimental appendectomy study. *BMC Surg.* 2020;20:116.
14. David LM, Abergel RP. Carbon dioxide laser blepharoplasty: conjunctival temperature during surgery. *J Dermatol Surg Oncol.* 1989;15:421–423.
15. Hammons MA, Ramey NA, Stinnett S, Woodward JA. Effects of reflected CO2 laser energy on operative field materials: risks to patients and operating room personnel. *Ophthalmic Plast Reconstr Surg.* 2010;26:386–388.
16. Mullins JB, Holds JB, Branham GH, Thomas JR. Complications of transconjunctival approach: a review of 400 cases. *Arch Otolaryngol Head Neck Surg.* 1997;123:385–388.