

CO₂ Laser Surgery Post-Operative Pain and Healing: A Partial Literature Review

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Introduction

Postoperative pain and risk of infection are the main concerns with surgery. Most studies testing postoperative pain are level 5 (case report) evidence or animal studies. There are no randomized studies on the matter, leading to prevalent skepticism in the medical and dental communities about whether the surgical technique used relates to postoperative pain. However, the plethora of case studies and the ever-increasing amount of anecdotal reports in the field of patient pain perception following CO₂ laser surgery indicate that there is basis for claiming reduced postoperative pain. This paper summarizes some of the existing research comparing postoperative pain and healing following CO₂ laser surgery with conventional blade or scissors.

Healing, Myofibroblasts and Post-Operative Wound Contraction

Studies of the soft tissue response to CO₂ laser surgery¹⁻²⁵ have found reduced wound contraction (scarring) and delayed wound healing compared to scalpel surgeries.

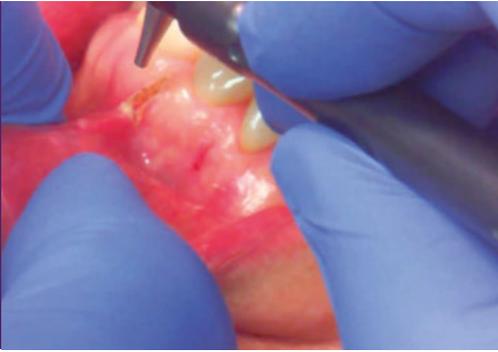
Slower healing of laser wounds (during inflammation and proliferation stages^{1,3,10}) has been attributed to the narrow zone of tissue denaturation at the margins and the coagulation of some connective tissue elements, and also to temporary postponement of inflammation, phagocytic resorption, collagen production and re-epithelization in the early stages of repair.¹⁹ Since CO₂ laser wounds are not as contracted as scalpel wounds, the larger surface area requires more time to re-epithelialize because cells have to migrate over a larger area.¹⁹ Zeinoun et al.¹⁰ reported a 3-day delay in re-epithelialization in CO₂ laser wounds (the process was completed in 10 days in laser wounds vs. 7-days in scalpel wounds). Sanders et al.²⁰ compared collagen thermal damage in pulsed and continuous-wave CO₂ laser incisions and concluded that pulsing can reduce delay in healing. It has also been shown that delays in early stages of the CO₂ laser wound healing are normally overcome at

later stages and do not appear to influence long-term outcomes.²¹ Minimizing thermal damage through lower power settings and active tissue cooling helps minimize the delayed healing.^{9,20,22-25}

Wound contraction and scarring during the remodeling phase of healing following CO₂ laser surgery is reduced compared to scalpel surgery.^{2,10,11} Myofibroblasts are stromal cells derived from fibroblasts and possess contractile features in common with smooth muscle cells.²⁶ They are key factors in fibromatosis and granulation tissue contraction during wound healing.²⁶⁻²⁸ Myofibroblasts have a specific capacity of developing cell-to-cell and cell-to-matrix connections thus acting on the whole tissue as a contractile network.²⁹ It has been shown that reduced wound contraction correlates to the reduced number of myofibroblasts and connective tissue trauma.^{30,31}

Zeinoun and colleagues¹⁰ analyzed the expression of myofibroblasts in healing CO₂ laser excisions and control excisions made by scalpel in the dorsal tongue mucosa of 144 rats. This study found that myofibroblasts appeared and disappeared slower, and in significantly fewer numbers, in CO₂ laser wounds. The lack of contractile myofibroblasts is suggested to be the reason for the minimal degree of contraction in healing CO₂ laser excision wounds. Similar results were found by Fisher et al.¹ and De Freitas et al.¹¹

Luomanen et al.³² compared healing scalpel wounds versus CO₂ laser wounds by looking at the extracellular matrix (ECM) components (such as laminin, Type IV collagen, Type III collagen, and fibronectin) in laser-treated rat tongue mucosa. The study found that laser treatment caused an extensive destruction of both epithelial and stro-



mal cells but left much of the connective tissue matrix relatively intact. The regenerative processes with concomitant re-epithelialization occurred slower in laser-treated wounds. This study also noted that CO₂ laser wounds differ drastically from burn wounds, which are characterized by the destruction of the connective tissue matrix, which results in notably more granulation tissue formation and wound contraction than is observed with healing of CO₂ laser wounds.³²⁻³⁵ The study concluded that relative resistance of the ECM proteins to CO₂ laser irradiation may account, at least partially, for the lack of contraction and scarring frequently observed in laser-treated areas. This may be another, less discussed, reason for less notable contraction of CO₂ laser wound, in addition to the smaller number of myofibroblasts at the laser surgical site.

To summarize, the following generalizations can be made based on the existing research about CO₂ laser wound healing and myofibroblasts that contract tissue during wound repair:^{8,27,28}

1. CO₂ laser wounds have fewer myofibroblasts than scalpel wounds;^{1,10,11}
2. CO₂ laser wounds display less contractility than scalpel wounds;^{1,10,11}
3. CO₂ laser-wound healing results in less scarring;^{1,5,10}

Post-Operative Pain, Healing and Return to Function

Many studies have reported lower levels of pain and discomfort following CO₂ laser surgery in oral soft tissues, compared with scalpel surgery.^{1,14,15,36,37}

In Haytac et al.¹¹ 40 patients in need of frenectomy were randomly assigned to have treatment either with a scalpel or with a SuperPulse⁴⁷ CO₂ laser. The surgical wounds

were left to heal by secondary intention. The postoperative pain and functional complications of each patient were recorded on days one and seven (a visual analog scale – VAS – was utilized). The CO₂ laser frenectomy patients reported significantly less postoperative pain and fewer functional complications (e.g. speaking and chewing) and required fewer analgesics in comparison with scalpel group patients. The study concluded that “when used correctly, the CO₂ laser offers a safe, effective, acceptable, and impressive alternative for frenectomy operations.”

In López-Jornet et al.¹⁵ study, 48 patients with oral leukoplakia were randomly assigned to receive treatment either with conventional scalpel surgery or with a CO₂ laser. The site of scalpel surgery was sutured, while the laser wound was left to heal by secondary intention. A visual analog scale (VAS) was utilized to rate the intensity of pain and swelling at different postoperative time points. The patients reported that pain and swelling following scalpel surgery exceeded those with the CO₂ laser (there were statistically significant differences between the two techniques during the first three days after surgery (p-value for related samples at 12 hours, 1, 2, and 3 days post-op ≤ 0.05). After that, pain gradually decreased over one week in both groups. The study concluded CO₂ laser surgery caused minimal pain and swelling and it may be an alternative to scalpel surgery in treating oral leukoplakia.

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“It seems likely that discomfort is less after laser surgery than by more conventional techniques and it is definitely less than discomfort after conventional surgery... Swelling and edema were virtually nonexistent after laser surgery”.

In another study the CO₂ laser was evaluated on 27 patients who underwent soft tissue pre-prosthetic surgery, including frenectomy, tuberosity reduction, hyperplasia removal, and sulcus deepening.⁴ The author pointed out that “it seems likely that discomfort is less after laser surgery than by more conventional techniques and it is definitely less than discomfort after conventional surgery with a secondary epithelialization technique. Swelling and edema were virtually nonexistent after laser surgery”. There was minimal swelling. Pain was moderate. Vestibular extension was created with mild-to-moderate discomfort,

controlled with medium-strength analgesics. “For frenectomies, the main advantages appear to be speed and a clean, bloodless field... For palatal hyperplasia and soft tissue tuberosity reduction, the laser appears to be faster and cleaner with less discomfort than is normally associated with this form of surgery by other techniques”.⁴ A third of the patients did not need analgesics. Reduced wound contraction was observed.

Niccoli-Filho et al.³⁸ described 15 cases where extensive epulis excision with maxillary or mandibular vestibuloplasty were carried out with a CO₂ laser. Patients reported minimal discomfort during the first 24 hours after the surgery, in stark contrast with conventional surgery experience with complaints of significant pain, sialorrhoea, dysphonia and dysphagia.

For scalpel surgery patients, postoperative edema interfered with oral hygiene, further impairing healing. Overall, the study found that removal of epulis with the CO₂ laser resulted in numerous notable improvements over conventional surgery, such as convenient removal of mucosa, lack of bleeding or need for sutures, and minimal postoperative pain and edema. In addition, the sites healed quickly, without complications, and both the esthetic and functional outcomes were excellent – all of the above allowed for more rapid placement of final prosthesis.

Wlodawsky and Strauss³⁹ presented several clinical cases showing CO₂ laser applications in intraoral surgery, such as mucocele excision, sialolithotomy, frenectomy, gin-

gival hyperplasia removal, vestibuloplasty, aphthous ulcer treatment, leukoplakia treatment, and others. One of their conclusions was that “the low morbidity and minimal pain generally associated with laser ablation makes it a valuable tool in the management of premalignant mucosal lesions.” Similarly, Mason et al.⁴⁰ found low morbidity and minimal pain to be important post-operative outcomes following the removal of gingival fibromatosis. After the CO₂ laser procedure, where the entire mouth was treated, no pressure packs were used and no sutures were placed. “Postoperative healing progressed with little discomfort or swelling and a satisfactory improvement in gingival contour and aesthetics was achieved.”⁴⁰

In van der Hem et al.,⁴¹ 39 oral lichen planus lesions in 21 patients were treated with a CO₂ laser. Although this study was retrospective with no control group, the researchers pointed out the reduction in pain was an interesting result.

Ishii et al.¹³ assessed the usefulness of CO₂ laser treatment of oral leukoplakia lesions in 116 patients. The study found laser excision suitable for leukoplakia lesions on non-keratinized epithelia, while laser vaporization can be used for the gingival cases of non-homogenous type leukoplakia. The authors reported damage to adjacent tissue is minimal (which reduces acute inflammatory reaction and postoperative pain, swelling, edema or infection); wound healing is excellent due to the limited contraction and scarring; and typically it is possible to leave the surgical defect to heal by secondary intention, which keeps functional disorders to a minimum because regeneration can occur without leaving postoperative cicatricial contractures. The study concluded CO₂ laser surgery was an excellent procedure for the management of oral leukoplakia which can prevent recurrence, malignant transformation, and postoperative dysfunction.

To summarize, there are numerous reports of reduced postoperative pain, although not always predictable, following CO₂ laser surgery.^{4,11,15,38-42} It was speculated to be the result of microcoagulation or “sealing” of nerve endings while severed nerve endings in scalpel wounds cannot anastomose.³⁶ It was also claimed that neuromas do not form.^{36,43}



By sealing blood and lymphatic vessels and nerve endings, laser surgery significantly reduces the local inflammatory response, leading to lower levels of glucocorticoids, epinephrine and norepinephrine, lowering the pain level.

However, Basu³ found neuronal hyperplasia and traumatic neuroma in all wounds. He rendered Carruth's hypothesis about "sealing" of nerve endings postoperatively unlikely and suggested that some other mechanism might be involved.³ The "nerve-sealing" theory also contradicts later research showing that the number of intact peripheral nerve structures in laser-treated sites was similar to the numbers in cautery- and scalpel-treated sites.⁴⁴ This, again, leaves the reasons for reduced postoperative pain unclear. Another proposed explanation is based on the finding that the CO₂ laser induces a spinal inhibitory effect via peripheral nerve stimulation, in other words, the activation of peripheral inhibitory nerves decreases neural signals from the spine to the cortex (gate theory).⁴⁵ Contrary to this, Tran et al.⁴⁶ documented a central somatosensory cortical effect of peripheral dermal stimulation with the CO₂ laser. Decreased pain is sometimes attributed to reduced mechanical trauma to the tissue (Gama et al.,⁴² and others). In sum, while several possible explanations have been proposed over the years, the exact mechanism that is accountable for reduced postoperative pain in CO₂ laser wounds compared to scalpel wounds is still unknown.

Recent Animal Studies on Post- and Intra-Operative Pain and Discomfort

Carreira et al.¹⁶ compared postoperative pain and healing after CO₂ laser surgery and

scalpel surgery. Laser group patients exhibited lower pain levels and higher post-op comfort than those in scalpel group. The CO₂ laser incisions were associated with lower white blood cell count (indicating reduced inflammatory response) and minor tissue trauma, because the endothelial wall does not incur as much injury as with scalpel incisions, thus decreasing the plasmatic protein total and serum albumin extravasation levels, and promoting healing.

Carreira et al.¹⁷ studied intra-operative hemodynamic responses (heart rate, various blood pressure parameters) in patients under general anesthesia and concluded that CO₂ laser was perceived as less painful than scalpel surgery. By sealing blood and lymphatic vessels and nerve endings, laser surgery significantly reduces the local inflammatory response, leading to lower levels of glucocorticoids, epinephrine and norepinephrine, lowering the pain level.

Silva et al.¹⁸ compared the plasma C-Reactive Protein (CRP) level variation between CO₂ laser surgery and scalpel surgery patients. CRP is an acute (inflammation) phase response protein. Peri-operatively, plasma CRP levels can help monitoring the level of tissue inflammation – the level of CRP correlates with the surgical trauma intensity in the patient. For CO₂ laser surgery patients, lower plasma CRP levels were registered than for scalpel group patients, i.e. the CO₂ laser in surgery was associated with lower inflammatory response, promoting a more comfortable peri-operative period for the patient.

Thus, all three above studies have shown that CO₂ laser incisions are associated with reduced inflammatory response, less postoperative pain, and better healing.

Summary

Several studies have found the reduced presence of contractile myofibroblasts – cells accountable for postoperative scarring – in CO₂ laser surgical wounds when compared to scalpel surgery. The authors of this review believe both the reduced production of myofibroblasts and reduced post-operative pain can be partially explained by the optimal depth of coagulation/hemostasis⁴⁷ on CO₂ laser surgical margins. Decreased extravasa-

tion of blood and lymphatic fluids into the CO₂ laser wound space impedes the release of inflammatory mediators.¹⁹ This results in less edema around the wound than following conventional surgery and delayed minimal inflammatory response.^{1,48} It may also account for the reduced immediate postoperative pain after CO₂ laser surgery. Despite the abundant research and anecdotal reports regarding diminished pain following CO₂ laser surgery, the exact mechanism behind it remains to be explained. **DSP**

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