Use of a 10,600-nm CO₂ Laser Mandibular Vestibular Extension in a Patient With a Chromosomal Abnormality

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Abstract: Vestibuloplasty involves a series of surgical procedures designed to restore alveolar ridge height by lowering the muscles attached to the buccal, labial, and lingual aspects of the jaws. The technique is indicated in cases of insufficient vestibular depth that may result from atrophy of the alveolar ridge and/or high attachment of muscle or movable mucosa. This article focuses on a carbon dioxide (CO₂) laser vestibular extension procedure performed in a patient with Klinefelter syndrome, which is caused by a chromosomal abnormality. The 10,600-nm CO₂ laser is shown to offer several advantages over a conventional scalpel and other laser wavelengths for soft-tissue pre-prosthetic surgery, including vestibular extension.

Learning Objectives
- describe the purpose and characteristics of vestibuloplasty
- discuss the significance of laser wavelength, laser pulsing, laser beam spot size, and power density for soft-tissue surgery
- explain the advantages of a CO₂ laser for soft-tissue surgery
- describe the difference in wound-healing mechanisms

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Soft-tissue pre-prosthetic surgery encompasses a number of procedures, such as epulis and denture hyperplasia removal, soft-tissue tuberosity reduction, frenectomy, vestibular deepening, and others. This article focuses on a carbon dioxide (CO₂) laser vestibular extension procedure performed in a patient with Klinefelter syndrome, which is caused by a chromosomal abnormality.

Vestibuloplasty is defined as any of a series of surgical procedures designed to restore alveolar ridge height by lowering the muscles attached to the buccal, labial, and lingual aspects of the jaws. This procedure is indicated in cases of insufficient vestibular depth that may result from atrophy of the alveolar ridge and/or high attachment of muscle or movable mucosa. Most vestibuloplasty techniques involve vestibular deepening on the buccal-labial side of the mandible. In some patients with severe alveolar bone resorption or high genioglossus and mylohyoid musculature attachment, the floor-of-the-mouth procedure could increase the lingual vestibular depth. In this case, extra attention should be paid to the underlying structures to preserve the function of the tongue and oropharyngeal musculature. The main goal of vestibuloplasty is to enlarge the denture-bearing area and to ensure the comfort, function, and stability of the denture.

A sufficient amount of alveolar bone should be present. Sometimes the severity of the alveolar bone resorption makes deepening of the vestibule impossible. In such cases, a bone graft may be required. Among other factors precluding vestibular deepening are the condition, amount, and/or composition of the mucosa. When extensive resorption of the mandible or maxilla occurs, the amount of stable surface bone may be insufficient to allow for an adequate denture to be made. Muscles in the mandibular such as the mylohyoid and genioglossus can interfere with the stability of the lower denture. In cases of poor mucosa condition, soft-tissue autogenous grafting or allografting may be necessary. Vestibuloplasty performed with grafting is associated with numerous postsurgical complications. Moreover, the need for a graft makes certain surgical modalities inapplicable for vestibular deepening (i.e., grafts do
not take on lasered epithelium, likely due to the insufficient exudate for nourishing the graft.

Prior to the vestibular procedure, taking a thorough history and performing a physical examination (visual, palpation, and radiograph) are necessary. Factors the clinician should consider include the patient's age, physical condition, family history, the amount and condition of the mucosa and underlying bone, and placement and tension of adjacent musculature.

Surgical Modalities
Traditionally, vestibular extension has been performed with a scalpel. Neckel conducted a study comparing scalpel and CO₂ laser vestibuloplasty. The results of the study indicated that both techniques ensured good vestibular depth gain. However, the patients receiving treatment with the CO₂ laser reported less pain and discomfort postoperatively than those receiving treatment with the scalpel.

In another study, Haytac and Ozcelik compared patient perceptions after frenectomies performed with the CO₂ laser and scalpel techniques. Patients perceived the CO₂ laser surgery more positively in terms of postoperative pain and function than traditional scalpel surgery. The article concluded that "the CO₂ laser offers a safe, effective, acceptable, and impressive alternative" to the scalpel. In the present authors' opinion, one of the disadvantages of a scalpel procedure compared to a CO₂ laser is intraoperative hemorrhage that needs to be managed.

In the past, electrosurgery has also been used for vestibuloplasty, but no modern studies support the use of this modality for vestibular extension. This is possibly due to the small thickness of the soft tissue and close proximity to the bone. In a study comparing thermal damages of the CO₂ laser with those created by electrosurgery in different types of soft tissue, Pogrel and colleagues concluded that the relatively narrow width of thermal tissue necrosis makes the CO₂ laser excision superior for histologic examination of excised specimens than those created by electrosurgery.

CO₂ Laser Soft-Tissue Oral Surgery
Not all lasers are equally efficient at both tissue vaporization (i.e., ablation, cutting) and coagulation. The difference is illustrated in the absorption spectra for main soft-tissue chromophores in Figure 1. Some dental laser wavelengths (approximately 3000 nm, such as erbium lasers) are well absorbed by the water-rich soft tissue and are excellent for ablation but not as efficient at coagulation. Other dental laser wavelengths (approximately 1000 nm, such as diode
FIG 2. Coagulation depth, H

Coagulation Depth, H

Widespread thermal damage
Gingival blood vessel diameters
Poor coagulation

H, mm

Near-IR 806-1,064 nm diodes
Coagulation depth H > blood-vessel diameter B

9.320-nm and 10,600-nm CO₂ lasers
Coagulation depth H < B blood-vessel diameter

2.780-nm and 2.940-nm erbium lasers
Coagulation depth H > B blood-vessel diameter

Wavelength, nm

Fig 2. Coagulation depth spectrum for pulsed laser ablation (Tₜ = thermal relaxation time). FIG 3. High peak power and short laser-pulse duration of the super pulse maximizes soft-tissue removal rate and limits collateral damage to the adjacent tissue. FIG 4. Laser-tissue incision with focused (0.25-mm spot) laser beam. Defocused beam (approximately 0.8-mm spot with nozzle approximately 10 mm from the tissue) with reduced fluence coagulates the tissue. FIG 5. Ablation depth in water-rich soft tissue with 10-W, 10,600-nm CO₂ dental laser at 3 W in the super pulse (150 Hz, 26.7 mJ; repeat F1-6, 20 Hz, 30 msec) mode.

and Nd:YAG lasers) are efficient at coagulation but inefficient at ablation because they are poorly absorbed by the soft tissue.

The 10,600-nm CO₂ laser wavelength is efficient at vaporizing and coagulating the soft tissue simultaneously (Figure 1), although it does not perform as well as an erbiium laser at ablation or a diode/Nd:YAG laser at coagulation. Most importantly, the CO₂ laser's coagulation depth closely matches the blood capillary diameters, as discussed in Wilder-Smith et al. and illustrated in Figure 2.

Laser pulsing is as important as wavelength; for cutting, short and powerful pulses are superior to long and weak ones. In the physics of pulsed laser surgery, thermal relaxation time is an important concept. Thermal relaxation time depends both on the tissue's light absorption coefficient (Figure 1) and the tissue's thermal diffusivity, as first described by Einstein. The irradiated tissue is vaporized with the highest efficiency if the thermal relaxation time is much longer than the pulse duration. The most efficient cooling of the tissue adjacent to the ablated zone is achieved when the period between laser pulses significantly exceeds the thermal relaxation time. Such laser pulsing specifications are referred to as a super pulse. A super pulse (Figure 3) minimizes collateral thermal damage, which makes it an essential feature of any state-of-the-art soft-tissue surgical CO₂ laser. The optimal combination of the CO₂ laser wavelength and these specific pulsing parameters ensures char-free, scar-free, and bloodless surgery with uncomplicated healing.

Laser Beam Spot Size

Just as the sharpness of the steel blade defines the quality and ease of the cut for traditional surgery, the size of the laser beam focal spot...
Fig 6. Preoperative view. Strong muscle attachments extended onto the crest of the ridge. Fig 7. A horizontal CO₂ laser incision was made across muscle attachments starting at the left second premolar level toward the right second premolar. Note tension applied to the lower lip. Fig 8. Immediately after the vestibular extension procedure with sutures in place. Fig 9. Two weeks postoperatively. Note good healing. Fig 10. Four weeks postoperatively. Note the absence of scarring. Fig 11. Final delivery. Patient with new dentures.
determines the quality of the cut in laser surgery. The smaller (or sharper) the focal spot of the beam, the narrower and deeper the incision. A dull blade cannot produce a quality incision; similarly, an oversized laser beam spot cannot produce a precise and narrow incision.

For cutting, a 10,600-nm CO₂ laser is maintained 1 mm to 3 mm away from the tissue and is moved at a “hand speed” of a few millimeters per second (Figure 4). For a rapid switch from cutting to photocoagulation, the laser beam can be defocused. Defocusing can be achieved by simply moving the handpiece away from the tissue (by approximately 10 mm for tipless laser handpieces), and “painting” the “bleeder” for enhanced hemostasis (Figure 4).

**Laser Power Density and Depth of Incision**

For a laser, the power density of the focused laser beam is equivalent to the mechanical pressure that is applied to a traditional scalpel blade. In other words, greater laser fluence (ie, greater power density, slower hand speed) results in greater depth and rate of soft tissue removal. When repetitive pulses are scanned across the soft tissue, the fluence is defined by the pulse frequency and the hand-speed; in other words, the depth of incision depends on laser power settings, spot size, and the surgeon’s hand speed.

Advantages of Soft-Tissue Oral Surgery With a CO₂ Laser

**Efficient Hemostasis**

The CO₂ laser’s excellent hemostasis and coagulation (due to the close match between coagulation depth and gingival blood-vessel diameters) allows practitioners to perform surgery even on extremely vascularized areas. The clinician benefits from improved visibility of the surgical field, which allows for highly precise and accurate tissue removal. Due to the efficient hemostasis, intraoral surgical wounds often do not require suturing or surgical dressing and can be left to heal by secondary intention.

**Minimal Postoperative Swelling**

Minimal postoperative swelling and edema can be expected with the CO₂ laser due to the intraoperative closure of lymphatic vessels on the margins of the laser incision. Lymphatic vessels regenerate approximately 8 to 10 days after capillary vessel proliferation.

**Reduced Postoperative Pain**

Although pain is generally difficult to evaluate, patients have reported moderate levels of pain with CO₂ laser surgery and often do not require analgesics. In the study by Niccoli-Filho et al., patients reported minimal discomfort only during the first 24 hours after the CO₂ laser surgery. Based on patient pain perceptions during frenectomies performed with a CO₂ laser, Haytaç and Ozcelie concluded that laser treatment was less painful than when performing the procedure conventionally with a scalpel.

In Neckel’s study, vestibuloplasty was performed on 40 patients, divided into two groups—one receiving a conventional blade and the other a CO₂ laser. Both showed a similar increase in the vestibular height, but patients in the CO₂ laser group reported less pain and discomfort. Strauss and Fallon and Deppe and Horsch compared the recovery process following CO₂ laser surgery, cryosurgery, and electrosurgery and reported healing was faster and less painful with the CO₂ laser.

**Healing and Less Risk of Scarring**

Minimized wound contraction and reduced risk for scar formation are among the biggest advantages of CO₂ laser surgery. Healing of CO₂ laser-irradiated wounds is characterized by a higher proliferation of fibroblasts that actively produce collagen. The findings of several studies indicate that in comparison with scalpel wounds, only a small number of myofibroblasts are present in the CO₂ laser surgical sites; reduced count of myofibroblasts results in minimal wound contraction and scar formation or fibrosis in laser-treated areas. Seventy-two hours after CO₂ laser surgery, the superficial necrotic layer of the laser-irradiated site is replaced by a fibrous membrane. Approximately 2 weeks after surgery, wound epithelialization begins from the periphery toward the center. The epithelial covering of the laser wound is parakeratotic; it is also thinner than the epithelium that forms after scalpel resection. The aforementioned factors could explain the good cosmesis after CO₂ laser surgery, which is characterized by smooth, elastic, new tissue and no fibrosis or scarring, whereas conventional surgery can result in some scarring. The combination of diminished wound contraction, minimized lateral tissue damage, precise control over the depth of incision, and excellent hemostatic efficiency makes the CO₂ laser a safe and effective alternative to the use of a traditional scalpel.

**Case Presentation**

A 30-year-old patient with Klinefelter syndrome (KS) requested a complete denture prosthesis. One of the most common chromosomal disorders in humans, KS is characterized by hypogonadism and genetically determined infertility. KS affects only men, occurring in individuals who have two or more X chromosomes (eg, 47,XXX or 48,XYYY instead of 46,XY). KS is associated with cognitive disorders, osteoporosis, tauroidontism, and dentofacial abnormalities. In cases of a rare variant of KS (49,XXXXY), permanent dentition may be completely absent.

The patient was high functioning but had a cognitive developmental disorder. Visual examination revealed bilateral microtia and hemifacial microsomia associated with this genetic disorder. He displayed minimal anxiety.

**Examination and Initial Findings**

The examination consisted of visual intraoral and extraoral inspection and palpation followed by radiography. The following areas were assessed: the presence of soft- or hard-tissue pathologies, the relationships of the jaws and remaining teeth, the amount and condition of the alveolar bone of soft tissue covering the denture-bearing area, the contour of the alveolar ridge, vestibular depth, and muscle attachments.

The examination revealed that the patient's mandibular muscle attachment extended onto the crest of the ridge (Figure 6). The muscle fibers created considerable tension. Radiographic findings showed mild alveolar bone resorption as well. Such muscle placement and condition of the bone made the mandibular vestibule space inadequate for substantial denture foundation and inhibited.
fabrication of a complete denture. The patient’s bilateral lingual tori had been previously removed, which provided adequate vestibular height on the lingual side of the mandibular ridge. Therefore, lingual vestibular extension was not required. To take a good impression and ensure a comfortable fit with satisfactory retention and stability of the denture, it was decided to perform buccal-labial vestibular extension with the CO₂ laser. The crest of the ridge and the soft-tissue condition did not require any grafting.

Procedure Equipment and Anesthesia
The procedure was performed in 1 session with a 10-W, 10,600-nm CO₂ dental laser with an angled tipless handpiece. A 27-gauge needle and 5-0 chronic catgut sutures were used. The laser was set to a focal laser spot of 0.25-mm diameter and a power setting of 4 W. A super pulse laser exposure mode was used (repeat pulse F2-3, 29 Hz, 15 msec, 44% duty cycle), and the average power to tissue was 1.76 W (je, 44% of 4 W). Anesthesia consisted of 2 caruples of 4% articaine with 1:100,000 epinephrine and bilateral mental nerve blocks.

Technique
The clinician pulled the lower lip outward to maintain tension and facilitate soft-tissue incision. A horizontal CO₂ laser incision was made starting at the left second premolar area and continued along the mucogingival junction line toward the second premolar of the contralateral side. The clinician made sure to extend the incision to the level of, but not through, the periosteum (Figure 7). Importantly, the trajectory of the incision was parallel to the bone surface. The small penetration depth of the CO₂ laser wavelength enabled the clinician to remove very thin layers of tissue without collateral thermal changes or mechanical trauma to the adjacent lateral and underlying tissues. Severing thicker muscle fibers required multiple laser passes rather than a single incision.

The small penetration depth is important for the vestibular extension procedure, because it gives the surgeon precise control over the depth of the incision. The surgeon, therefore, is able to deepen the incision until the level of periosteum is reached without inadvertently cutting through it.

The freely movable mucosa flap was then carefully lowered to the level of the deepened vestibule and immobilized with resorbable sutures. The patient did not have a preexisting denture to hold retracted muscle tissue in the desired position. Therefore, the tissues were tacked down, as far apical as possible, using individual sutures. Connecting the suture in a continuous manner was not an option. If one had separated the tissue, it might have folded back. Sutures were left to resorb on their own (Figure 8). No bleeding was present, so no additional manipulations of the surgical site were needed.

Postoperative Care
The patient was released from the clinic immediately after the procedure and placed on amoxicillin (250 mg four times daily for 10 days). He was given vitamin E in gel form to place on tissue twice daily using an extremely gentle, nonabrasive 12,000-bristle surgical brush. The patient was also given an organic, alcohol-free irrigation product to debride the area before rinsing it with salt water twice daily. Dietary instructions included the restriction of rough or abrasive foods, such as potato chips or crackers.

Follow-up Examinations
Follow-up examination 2 weeks postoperatively showed good epithelialization (Figure 9). Four weeks after the vestibular extension procedure, the surgical site had healed completely with smooth pliable tissue and no scarring (Figure 10). Impressions were taken 6 weeks after the surgery.

The vestibule depth increased by 8 mm. The achieved vestibule height allowed for efficient stable denture placement (final delivery is shown in Figure 11). The patient was satisfied with the result.

Conclusion
The 10,600-nm CO₂ laser offers numerous advantages over a conventional scalpel and other laser wavelengths for soft-tissue preprosthetic surgery, including the vestibular extension procedure. The benefits, which include speed, excellent hemostasis, absence of inflammation, reduced pain, and good patient acceptance, are especially important in patients with various developmental disorders, such as in the case reported in this article.

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