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Lasers in contemporary oral and maxillofacial surgery

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Lasers are becoming the standard of care for many oral and maxillofacial procedures, and they are being introduced as an efficient instrument for a variety of new applications within the specialty. The practice of oral and maxillofacial surgery (OMS) has included the use of lasers since the mid-1960s [1]. Lasers are becoming increasingly popular due to the advent of office-based lasers, which are small, portable, and easy to manipulate within the oral cavity. Based on manufacturer estimates, approximately 10% to 20% of all oral and maxillofacial surgeons use a laser in office-based practice, and most have access to lasers in the hospital. Lasers enhance the current surgical options for treatment and have contributed to the expanded scope of OMS.

Lasers traditionally have been used in OMS for preprosthetic surgery, for the excision of benign and malignant lesions, for the excision of vascular lesions, and in the treatment of coagulopathic patients. The incorporation of lasers in OMS has been well documented. Goldman [2] applied laser energy to teeth and soft tissues in 1965. Strong et al [3] used carbon dioxide (CO_2) lasers in the early 1970s for a variety of surgical procedures, including the excision of malignant and premalignant lesions. Kaplan et al [4] removed benign tumors and superficial oral cavity cancers. Using the argon laser instead of the CO_2 laser, Apfelberg [5] removed vascular lesions, such as hemangiomas and nevus flammeus, from the maxillofacial region. Hemophilic patients benefited significantly from Ackermann's [6] use of the neodymium:yttrium-aluminum-garnet (Nd:YAG) laser for a variety of oral surgical conditions. Lasers rapidly became a predictable and favorable

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treatment modality for leukoplakia, hemangioma, epulis, granuloma fissuratum, and nevus flammeus and patients with clotting disturbances.

As oral and maxillofacial surgeons have become more comfortable using lasers in clinical practice, many new procedures have been developed specifically to take advantage of the unique properties of these devices. The introduction of the laser for use in the maxillofacial region also led to the development of other procedures, such as laser skin resurfacing, which would not have been possible with a scalpel or electrocautery. Some procedures, although possible with other modalities, have become associated with the laser because of its inherent advantages for the specific procedures, such as hemostasis, decreased scarring, and diminished postoperative pain [7]. These advantages are discussed in detail throughout this issue. The management of patients with sleep apnea, temporomandibular joint (TMJ) derangements, dental implants, premalignant lesions, and posttraumatic facial scarring has changed dramatically with the evolution of laser surgery.

Lasers for oral and maxillofacial surgery

Many different laser wavelengths have been used in OMS. Depending on the laser's characteristics, one can select the type of laser most applicable under the given circumstances. Because of its excellent affinity for water-based soft tissues, the CO_2 laser, at 10,600 nm wavelength, is one of the most widely employed lasers in OMS. Use of the CO_2 laser has been described extensively by many authors [7–10]. The CO_2 laser is ideal for most soft tissue surgeries performed intraorally and extraorally. The absorbed energy causes vaporization of the intracellular and extracellular fluid, and blood vessels of approximately 500 μ or less are sealed spontaneously. The introduction of hollow waveguide technology during the 1980s made CO_2 lasers even easier to use. The waveguide enables the beam to be delivered closer to the tissue and allows the surgeon better visualization of the operating field. This delivery system replaced the burdensome articulating arms and offers extreme ease of access to all areas of the oral cavity.

The CO_2 laser is only one of a growing family of lasers used in OMS. Many other laser wavelengths have been used for various indications that best take advantage of the properties of that particular wavelength. The Nd:YAG laser has different characteristics compared with the CO_2 laser. The Nd:YAG laser's active medium is a crystal of yttrium, aluminum, and garnet doped with neodymium ions [11]. By functioning in the near infrared spectrum at 1064 nm, the Nd:YAG laser exhibits minimal surface tissue absorption and maximal penetration; this allows for coagulation of tissue in depth so that vessels 2 to 3 mm in diameter can be ablated. The Nd:YAG laser is a free-running pulsed laser that can be delivered through a pure optical fiber. Because the pulse duration is shorter than the time required to initiate a nerve action potential, Romanos [12] believed that most procedures could be performed without local anesthesia. White et al [13] compared

Nd:YAG laser surgery with conventional scalpel surgery and concluded that the laser could be used successfully for intraoral soft tissue applications without anesthesia and with minimal bleeding. Experience has shown, however, that for patient comfort, any procedure involving significant ablation or resection of tissue needs anesthesia. The Nd:YAG laser also is unique in that it can be used in a contact (excision) and a noncontact (coagulation) mode. These properties have led to its use in a variety of maxillofacial procedures, including coagulation of angiomatous lesions, hemostasis in bleeding disorders, arthroscopic surgery of the TMJ, resections in vascular tissues (in combination with the CO_2 wavelength), and palliation of advanced neoplasms [14].

The erbium:YAG (Er:YAG) laser has become increasingly popular because of its usefulness in dental implant and cosmetic facial surgery. Because its 2940-nm wavelength is highly absorbed in water, the Er:YAG laser is useful in various OMS procedures. It is a free-running pulsed laser whose thermal effects interact solely with the surface layers of soft and hard tissue [15]. These properties have made the Er:YAG laser particularly attractive for use in dental implant surgery. Because the beam is reflected by polished metal surfaces, it has no adverse effects on titanium surfaces [16]. Application of the Er:YAG laser in dental implant surgery has been advocated for the preparation of hard tissue, second-stage surgery, revision of soft tissue, and treatment of peri-implantitis [17–19]. The Er:YAG laser also has enjoyed considerable growth in the area of facial cosmetic surgery. Although controversy exists regarding the optimal laser treatment for facial rhytides, it has been suggested that the Er:YAG laser is the ideal tool for superficial resurfacing because it results in less thermal damage and fibroplasia than the CO_2 laser [20]. Its only detraction is the minimal depth of effect compared with CO_2 laser resurfacing.

The holmium:YAG (Ho:YAG) laser is used predominantly in OMS for TMJ surgery and provides superior accuracy in treating intra-articular tissues with improved surgical access [21]. A yttrium, aluminum, and garnet crystal, doped with holmium, is used to generate a 2100-nm wavelength. This wavelength allows for transmission through an optical fiber (quartz), and the radiation is delivered to the tissues in a contact mode [22]. Consequently, there is minimal lateral heat transfer, which allows for precise cutting and control of tissue depth penetration. The Ho:YAG laser offers less peripheral tissue damage, profound hemostasis, and controlled depth of penetration compared with surgical intervention with shavers and scalpels (ie, mechanical devices) [23]. The Ho:YAG laser can be used easily through saline solution or lactated Ringer's solution. All of these characteristics make the Ho:YAG laser the perfect instrument for TMJ arthroscopic procedures, such as diskoplasty, diskectomy, and synovectomy [24].

With a wavelength of 514 nm, the argon laser is indicated for treatment of dermatologic, labial, and oral lesions with a large vascular component. The argon laser is absorbed by pigment-containing tissues, including hemoglobin in erythrocytes, melanin in melanocytes, and other dark pigments. At this wavelength, the laser beam is not significantly absorbed by water and is able to spare superficial epidermal layers from damage. Although the argon laser is effective in treating various vascular lesions, it has been shown to be ineffective in deeper lesions or lesions of inappropriate color [25].

Semiconductor diode lasers have proved to be portable, compact, comparatively inexpensive surgical units with efficient and reliable benefits for use in OMS. Diode lasers have a wavelength between 805 and 980 nm. Depending on the clinical scenario, they can be used in continuous or gated pulse modes with contact or noncontact handpieces. At a wavelength of 980 nm, the optical penetration is less than that of the Nd:YAG laser (1064 nm); this is potentially beneficial for the treatment of superficial and interstitial lesions. Romanos and Nentwig [26] found that the incision margin using the diode laser is more precise compared with other systems, including the CO_2 and Nd:YAG lasers. In addition to various soft tissue oral surgical procedures, the diode lasers have become popular in the treatment of peri-implantitis because they offer a bactericidal effect without causing implant surface alterations [27].

Principles of laser physics for oral and maxillofacial surgery

With any medical or dental procedure using a laser, a thorough understanding of the physics involved and the differences between systems is important if a successful and safe outcome is to be expected. Soft tissue surgery with a laser is deceptively simple, but grave consequences can result if the principles of appropriate laser physics, beam modulation, and beam delivery are not integrated carefully into the procedure.

Currently, most applications of lasers in OMS are restricted to soft tissues of the face and oral cavity. The most commonly used lasers are the CO_2 and Er:YAG, both of which are absorbed primarily by water. Absorption into the target tissue results in four effects: photoacoustic, photochemical, photoablation, and photothermal. The photothermal effect, or the generation of heat, plays the most significant role. Because these lasers are so well absorbed by water, they are essentially totally absorbed within the first 0.1 mm of the tissue surface, causing, at 100°C, the intracellular water to vaporize and expand, leading to cellular rupture and loss of 75% to 95% of the cell volume as steam. At higher temperatures, the residual organic matrix also vaporizes, resulting in total tissue ablation.

Given enough time, the heat that is generated begins to leak laterally by thermal conduction, leading to a series of concentric circles of diminishing heat radiating outward from the target (Fig. 1). This lateral thermal damage zone may extend to 500 μm from the target with a CO_2 laser [28]; considerably less damage occurs with the Er:YAG laser (20 μm). Although this is a small zone of adjacent thermal damage when considering most intraoral uses and leads to useful hemostasis, 500 μm of thermal damage in

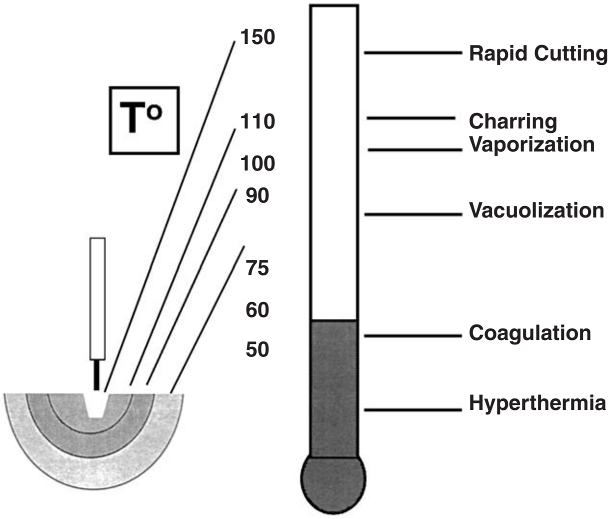

Fig. 1. Lateral conduction of heat generated by the laser into the adjacent tissue yields varying degrees of tissue effects. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:853; with permission.)

skin uniformly results in scarring. Control of lateral thermal damage is paramount to the use of lasers in OMS.

Control of the extent of lateral thermal damage is based primarily on the speed of the laser application; the faster the pulse, the less time available for conduction into adjacent tissues. Flashlamp-pumped or optically pulsed lasers can pulse faster than the tissue can begin to conduct significant heat laterally and can minimize lateral thermal damage. Although the Er:YAG laser is capable of this phenomenon, the CO_2 laser cannot be optically pulsed. Continuous-wave CO_2 lasers can be gated or shuttered or, for even shorter pulses, can be *superpulsed* or *ultrapulsed* (a means of obtaining high powers for short periods by briefly overpumping the laser tube). These methods allow pulses at or below the thermal relaxation time of most tissues, including epidermis, and allow for surgery with minimal collateral damage when desired.

Three parameters controllable by the surgeon function to control the laser's effect on tissues: power, time on target, and effective spot size of the beam. Two important measures of the effect of the laser are power density and energy density, or fluence. Power density is a measure of the amount of power per unit area that it is applied to and is represented by the following formula:

$$PD = \text{power/unit area} = W/cm^2$$

Power density is a good measure of the speed of laser depth effect. By increasing power or using a smaller spot size, the laser goes deeper with each second of application. Decreasing power or increasing spot size lessens the depth per second (Fig. 2).

The total amount of energy applied to a unit of tissue and the total volume of tissue removed by the laser are defined as fluence and are represented by the following formula:

$$\text{Fluence} = \text{joules}/\text{cm}^2$$

By adjusting these parameters, one can create a deep thin cut into tissue for incision or excision or a wide superficial surface vaporization for tissue ablation. Manipulation of these parameters becomes important when performing procedures in which minimizing lateral damage is crucial to prevent scarring (eg, skin resurfacing).

Advantages and disadvantages

There are many advantages to the use of lasers in OMS. Nevertheless, it is incumbent on the surgeon to use the laser only when these advantages outweigh the increased risk and cost of its use. The hemostatic nature of the laser is of great value in OMS. It allows surgery to be performed more precisely and accurately because the surgeon has increased visibility of the surgical site.

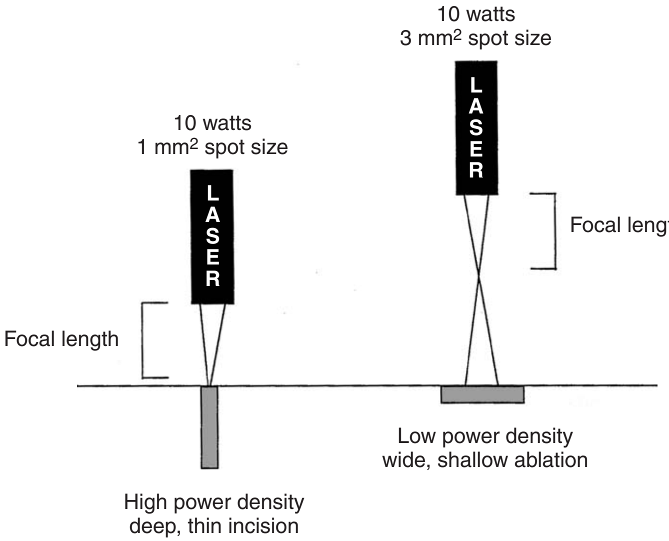

Fig. 2. Power density has a dramatic effect on determining the depth and surface area affected. Although these two lasers are generating the same power, the varying spot sizes alter the power density and affect tissues differently. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:854; with permission.)

Decreased postoperative swelling is characteristic of laser use [29]. Decreased swelling allows for increased safety when performing surgery within the airway and increases the range of surgery that oral and maxillofacial surgeons can perform safely without fear of airway compromise. This effect allows the surgeon to perform many procedures in an office or outpatient facility that previously would have required hospitalization for airway observation, postoperative nursing care, and parenteral pain management.

Tissue healing and scarring also are improved with the use of the laser [30,31]. This improvement is due to a combination of decreased lateral tissue damage, less traumatic surgery, more precise control of the depth of tissue damage, and fewer myofibroblasts in laser wounds compared with scalpel wounds. When lasers are used intraorally, laser wounds generally heal with minimal scar formation and soft, pliable residual tissue. Because of this improved healing and hemostasis, intraoral laser wounds often can be left unsutured except when cosmesis is an issue.

Although not always predictable, decreased postoperative pain often can be obtained with the use of lasers for surgery. The physiology of this effect is still unknown but probably relates to decreased tissue trauma and an alteration of neural transmission. As with decreased swelling, this aspect has enabled surgeons to perform many procedures on an outpatient basis, with patients returning to work within 1 day or even immediately in many cases. This advantage becomes most evident in the management of extremely large lesions, in which traditional surgery often required parenteral drugs for pain control and in which laser surgery almost always requires nothing stronger than class III narcotics.

Despite the many advantages for OMS, there are disadvantages that also must be weighed carefully before choosing this modality for patient treatment. Although oral and maxillofacial surgeons would delight at using lasers for osseous surgery (eg, extraction of impacted teeth and osteotomies), the speed of the Er:YAG for osseous tissue removal does not yet compare favorably with conventional techniques, in the authors' opinion. As previously mentioned, healing from laser surgery is usually excellent, with decreased scarring and increased function; however, the speed of healing usually is prolonged compared with other types of wounds [32]. This delay in healing undoubtedly is due to the sealing of blood vessels and lymphatics and the subsequent need for neovascularization for healing. Typical intraoral healing takes 2 to 3 weeks for wounds that normally would take 7 to 10 days, and this must be taken into account when considering suture removal (assuming that sutures have been placed) and obtaining patient consent.

Techniques for use in oral and maxillofacial surgery

There are basically three photothermal techniques for laser use on soft tissues within the oral cavity and on the face: incisional procedures, vaporization procedures, and hemostasis. When these three techniques are understood, the surgeon only has to decide which one would treat the lesion in question most appropriately and how to control the laser parameters of power, time, and spot size to affect the target best with the least collateral damage.

Incisional and excisional procedures using the carbon dioxide laser

A common use of lasers in OMS is to use the device essentially as a light scalpel, using the laser to make relatively deep, thin cuts much as one would do with a scalpel blade. This technique allows the surgeon to perform almost any intraoral procedure that normally would be done with a scalpel, such as incisional or excisional biopsy, lesion removal, or incision for flap access [33].

Understanding the physics involved, it is easy to see that this technique would require a fairly high-power density using a small spot size to create a deep but thin cut, as would be needed to make an incision. It is generally ideal to keep the spot size to whatever is the smallest practical spot size possible with the particular laser (usually 0.1–0.5 mm) because this results in the thinnest cut, closely replicating the cut made with a standard scalpel blade. This approach is called *focused mode* because the smallest possible spot size occurs at the focal length of any particular laser, which varies from 1 mm to about 1 cm from the end of the handpiece.

The basic technique for incision and excision remains the same no matter the particular system used and is shown in Fig. 3. It is always a good idea to begin the procedure by outlining the intended incision line. This outlining can be done on most machines by using an intermittent, pulsed, or gated mode with a rate of 10 to 20 pulses per second and a low enough fluence per pulse to allow for a superficial mark on the surface of the target without deep penetration. This approach allows the surgeon to delineate the needed margins, if any, in a slow, controlled motion and allows the procedure to be repeated and adjusted. When this procedure is completed, the laser can be changed to a continuous mode, and the dots are connected to create the desired incision. This connection should be done in a rapid yet controllable, continuous fashion to create a single-depth cut with minimal adjacent thermal damage. If a single pass is inadequate to obtain the desired depth, a second pass can be performed and repeated as necessary until the appropriate depth is reached, usually the submucosa for most oral lesions.

Because of the many uncontrollable factors that determine the depth of effect of the laser into any particular tissue and the three clinician-controlled parameters mentioned already (power, time, and spot size), it is impossible to generalize on the specific laser parameters for any individual lesion. It is more important to consider each use as a unique circumstance and to adjust the parameters to provide the best result on the target, in the most controllable manner, with the least lateral thermal damage. Typical spot

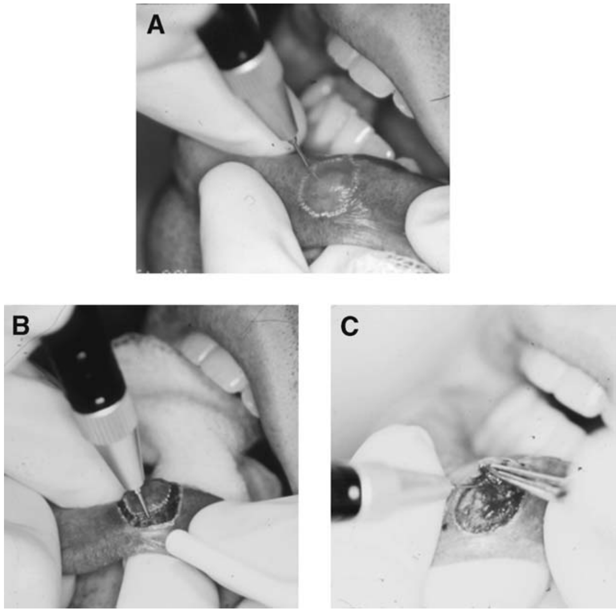

Fig. 3. The basic technique for laser excision demonstrated in the removal of a mucocele. (*A*) Outlining specimen in a repeating pulse fashion. (*B*) Connecting outlined dots to create a vertical cut around lesion. (*C*) Undermining and removing the specimen. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:858; with permission.)

sizes of 0.1 to 0.5 mm and a power of 4 to 10 W usually are good to initiate treatment for most intraoral incisions.

Observation of the effect of the laser parameters during the first pass enables the surgeon to determine the appropriateness of those parameters and any needed adjustments to make subsequent passes more effective. If the depth is inadequate during the initial pass, there are two options for the surgeon. The power may be increased, or the handpiece may be moved more slowly to increase time. Unless needed for control, the latter choice is always less ideal because this allows more time for lateral conduction.

Conversely, if the depth is too great, the power can be lowered or the handpiece moved more quickly to lessen the depth. Spot size should not be adjusted for incisions. At the conclusion of a single pass, further passes can be made, with similar adjustments accomplished to idealize the depth.

When the appropriate depth has been reached, excision can be performed by grasping the tissue with a forceps, applying slight traction, and horizontally undermining the tissue in the same fashion as a blade with the laser still in focused mode. Appropriate steps should be taken to prevent inadvertent damage to adjacent and more posterior tissues by the laser when it has passed through the ends of the specimen. These steps may include wet

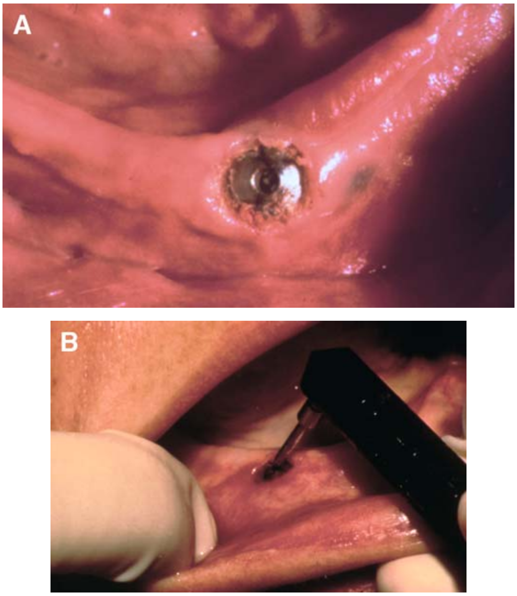

Fig. 4. Excision of tissue for second-stage implant surgery. (*A*) Note lateral angulation of laser for exposure to avoid direct contact with implant fixture. An attempt should be made to minimize removal of attached tissue. (*B*) Exposure of implant.

gauze or a wet tongue blade behind the target, using the water to absorb errant laser energy and minimizing possible tissue damage and fire hazard.

Closure of incisions and excisions performed with a laser are often at the discretion of the surgeon. Because bleeding and scarring usually are minimized, and postoperative pain does not seem to be related to closure, sutures are absolutely required only for cosmesis, when leaving the wound to granulate slowly would present an unacceptable cosmetic situation.

Any soft tissue lesion that requires excision for histologic examination is best treated using this technique. Typical lesions treated by excision and incision include the following (Figs. 4–6):

Fibroma
Mucocele
Papilloma
Gingival lesions
Benign salivary gland lesions
Salivary stones
Malignancy removal
Incisional biopsy
Excisional biopsy
Vestibuloplasty
Epulis fissurata

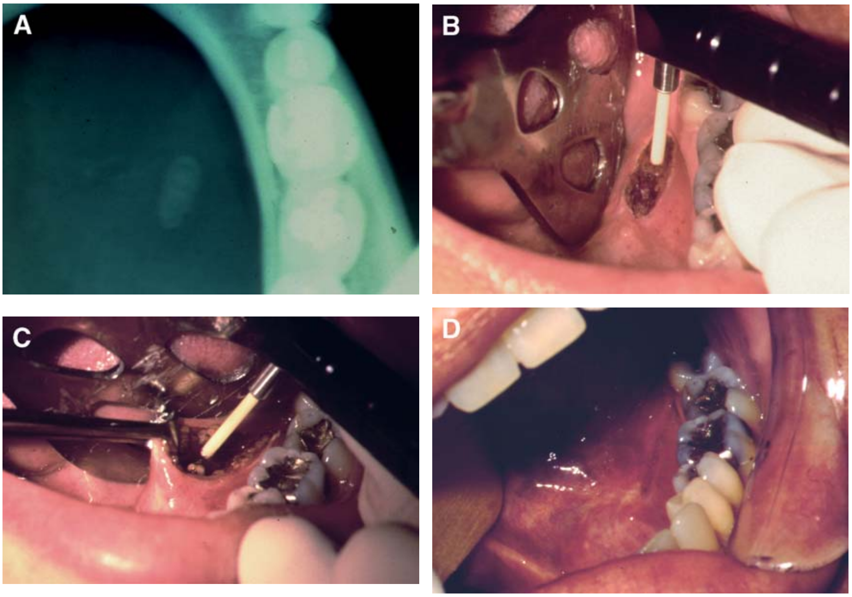

Fig. 5. Salivary calculi removal. (*A*) Occlusal radiograph showing radiopaque mass consistent with a sialolith. (*B*) Excision of floor-of-mouth mucosa for exposure of sialolith. (*C*) Calculi visualized (confirmed by production of spark). (*D*) Resultant tissue defect left unsutured.

Hyperplastic tissue excision
Implant uncovering
Peri-implantitis
Laser-assisted uvulopalatoplasty (LAUP)
Tongue lesions

Laser excision is most desirable for any solid, exophytic-type lesion. It also is excellent for tissue removal for preprosthetic surgery because of the improved visibility and precise control of tissue removal afforded. The technique is *lesion independent*; any lesion or tissue requiring excision or incision is treated using the same basic method.

Ablation and vaporization procedures

Although using a laser to make an incision has many advantages, the laser excels in performing vaporization procedures. Tissue ablation (also called *vaporization*) is used when the surgeon wishes to remove only the surface of the target or to perform a superficial removal of tissue. In these situations, the lesion usually is confined to the epithelium or to the epithelium and underlying superficial submucosa. Standard excision generally leads to removal of tissue deeper than necessary with increased scarring, bleeding, and possible damage to important adjacent structures. It is possible to manipulate

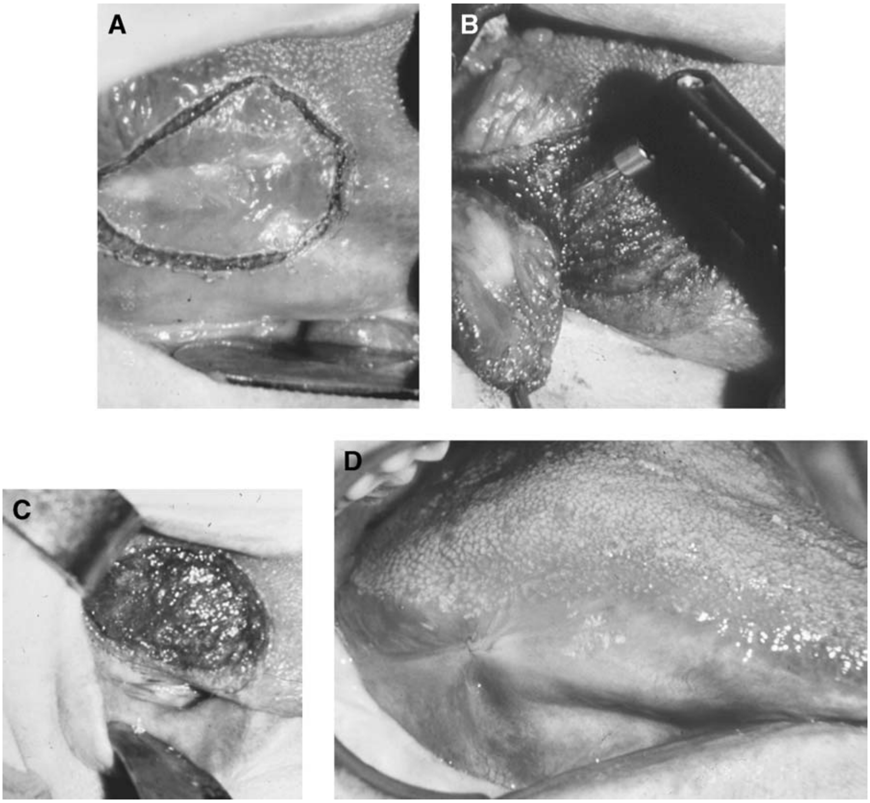

Fig. 6. Excision of T1N0M0 carcinoma of lateral tongue. (*A*) Outline of lesion. (*B*) Undermining and excision of lesion. (*C*) Resultant defect with large margins left unsutured. (*D*) Two-year postoperative view displays excellent healing with minimal scarring and functional deficit. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:861; with permission.)

laser parameters to confine removal to just the involved layers with minimal damage to underlying tissues and structures. Improved healing results with less scarring and dysfunction. The only other modalities capable of approximating this effect are cryosurgery and chemical peeling, and the laser is considerably more predictable in controlling depth than either of these.

The technique for vaporization begins with the same outlining procedure that is used for excision. This approach allows the surgeon to demarcate clearly the extent of the vaporization and any needed margins in a controlled, slow fashion using an intermittent pulsing mode. At this point, the laser is *defocused* by pulling the laser back from the target and allowing the beam to widen. A spot size of 1.5 to 3 mm is typical for most intraoral vaporization procedures and provides a reasonable area of coverage. The defocused beam is traversed along the lesion in a series of vertical strokes, represented as

Fig. 7. Ablation of papillary hyperplasia. Notice the horizontal defocused ablation using side-by-side "U's". (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:866; with permission.)

side-by-side "U's" as seen in Fig. 7. It is important to avoid excessively overlapping areas that would lead to a doubling of the fluence and depth. Missing areas could lead to lack of eradication of the lesion. In addition, a constant speed must be maintained to create uniform depth.

Similar to incisions, it is impossible to define a specific power or spot size for any particular procedure, but 4 to 10 W with a spot size of 1.5 to 3 mm usually provides an acceptable starting point for most tissues. Increasing depth can be accomplished by increasing power (good), moving slower to increase time (bad, owing to time for thermal conduction), or decreasing spot size (acceptable, but less ideal because of increased number of strokes needed to cover area). To decrease depth, the surgeon can decrease power (acceptable, but not ideal), move faster (best, if control is still maintained), or widen the spot size (also a good choice). If the first pass is inadequate, one or more additional passes can be made. Subsequent to each pass, any surface char should be removed gently with a wet gauze because this layer contains no water for absorption of the laser beam and results in prolonged heating and excess lateral thermal conduction. This technique allows for removal of a surface lesion in layers of a few hundred microns to 1 to 2 mm at a time.

Ablation can be used whenever small amounts of tissue need to be removed, regardless of whether they are superficial or not. During apicoectomy, the apex is exposed by a standard bur or by Er:YAG laser, then the periapical soft tissue can be removed with the CO_2 laser rather than curetted with hand instruments. The standard technique of defocused ablation is used. If the CO_2 laser interacts with bone, this may result in minute amounts of necrosis, but this is minor compared with the excellent removal of tissue remnants possible with this technique.

Ablation techniques preclude an excisional biopsy of the specimen. In situations in which a neoplasm is involved, it is imperative to have a firm grasp of the histologic diagnosis before considering ablation of the lesion. For larger surface lesions, such as leukoplakias, histologic diagnosis is best accomplished using multiple biopsy specimens (Fig. 8) or toluidine blue

Fig. 8. Multiple biopsy specimens of tongue taken with laser. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:864; with permission.)

staining. Brush biopsy also may play a role in these cases to ensure a definitive diagnosis. If the lesion turns out to be benign, it can be ablated; if it turns out to be malignant, the procedure can be changed to wide laser excision. Typical lesions treated by vaporization include the following (Figs. 9 and 10):

Leukoplakias
Dysplasia
Lichen planus
Papillary hyperplasia
Hyperkeratosis
Oral melanosis
Nicotine stomatitis
Papillomatosis
Tissue hyperplasia
Actinic cheilitis

Similar to incisional procedures, the technique is lesion and tissue independent. Any superficial tissue removal without the need for histologic examination can be treated in a similar fashion.

Leukoplakia, erythroplakia, and mixed forms of these lesions are potentially premalignant. Patients with this condition experience a 50- to 60-fold greater risk of developing oral cancer than the remainder of the population. The management of these lesions has always been controversial. Interventional laser excision or ablation of precancerous oral epithelial lesions offers unique advantages, however, compared with scalpel excision, including rapid removal of diseased tissue, control of bleeding, precise removal of lesional tissue, good patient acceptance, low morbidity and complications, and favorable healing [34]. Nevertheless, there has been much debate regarding the efficacy of laser surgery for treatment of these lesions. Thompson and Wylie [35] addressed this issue by reviewing 57 consecutive laser-treated patients presenting over a 4-year period with histologically confirmed dysplastic lesions. Over a 44-month period, they found that 76%

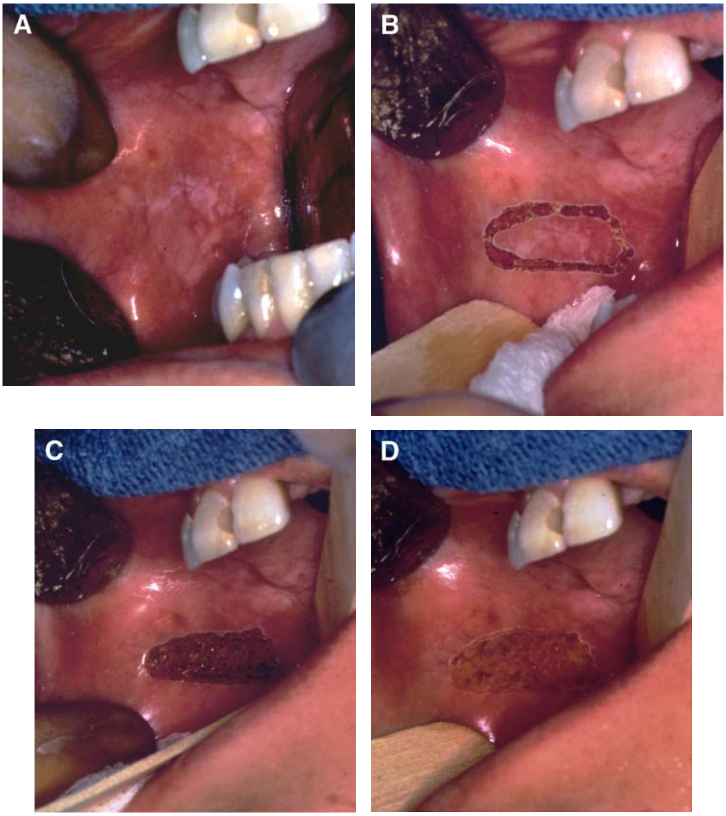

Fig. 9. Laser ablation of leukoplakia of buccal mucosa. (*A*) Diffuse leukoplakia of buccal mucosa. (*B*) Outline of lesion. (*C*) Ablation completed and char layer removed. (*D*) Resultant tissue defect left unsutured.

of these patients remained disease-free, which is essentially identical to the 80% success rate in patients treated with surgical excision. Laser vaporization is an effective, nonmorbid, inexpensive, quick, and relatively painless method of managing premalignant lesions. Many clinicians believe that the hemostatic effect of the laser results in decreased tendency for hematogenous or lymphatic seeding of the malignant cells [36,37].

Hemostasis techniques

As previously mentioned, lasers generally result in bloodless surgical fields. Even in cases in which other modalities of treatment have been used, the laser can be used as a hemostatic tool to stop bleeding in the field and to allow for similar postoperative wound management. The cause of hemostasis is not coagulation of blood, but rather the contraction of the vascular wall collagen. This contraction results in constriction of the vessel opening and

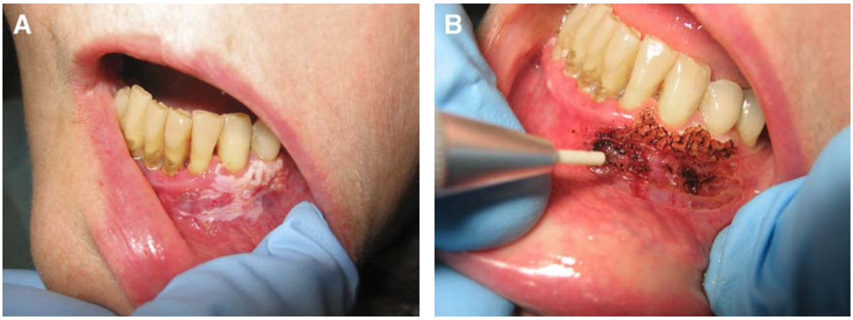

Fig. 10. Premalignant lesion of mandibular gingiva. (*A*) Preoperative photograph shows extensive growth, making excisional procedure difficult. (*B*) Defocused ablation of gingival lesion with remaining char layer.

hemostasis. It is incumbent on the surgeon to ensure a saliva-free field before beginning lasing of the tissue for hemostasis.

The technique used generally is similar to vaporization but employs a smaller spot size. The laser is passed over the tissue similar to that done in a vaporization procedure, until bleeding ceases. If bleeding continues, it is an indication that a vessel greater in diameter than the spot size of the laser is involved, and other, more conventional hemostatic techniques (packing, sutures) are required.

Cosmetic laser surgery

As the scope of OMS has increased over the years, oral and maxillofacial surgeons have started using lasers for patients interested in cosmetic facial surgery. A common procedure performed is cosmetic skin resurfacing. This procedure treats facial lesions (Figs. 11 and 12) and skin wrinkles (Figs. 13

Fig. 11. Ablation of facial lesion using a Superpulse CO_2 laser. Lack of char layer resulting from minimal lateral thermal damage of underlying tissues. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:869; with permission.)

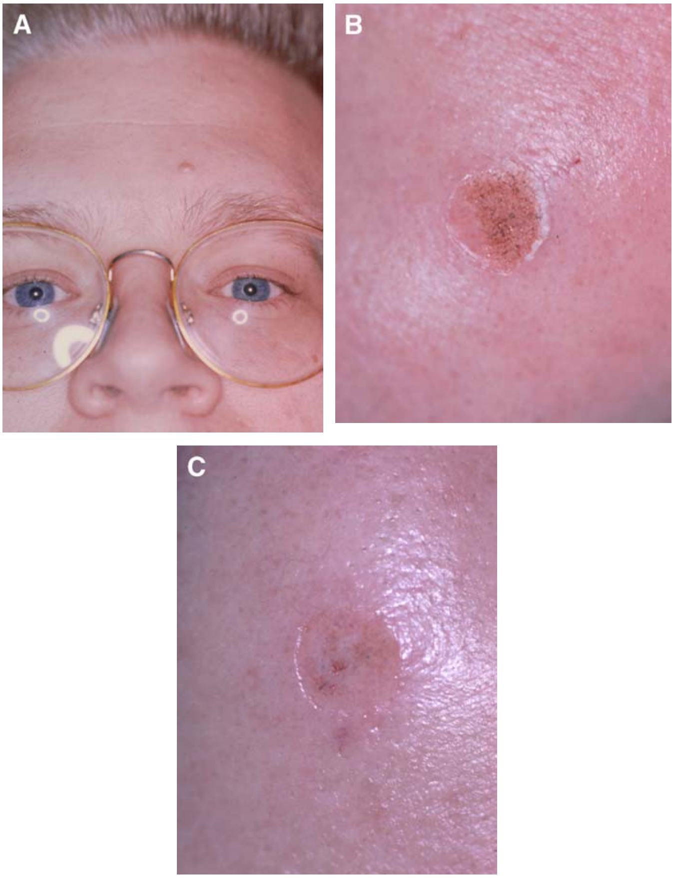

Fig. 12. Ablation of pigmented facial nevus. (*A*) Pigmented facial nevus on left brow. (*B*) Resultant char layer after ablation of pigmented lesion. (*C*) Removal of char layer shows lack of remaining pigment.

and 14) by removing the surface layer of the epidermis and superficial papillary dermis, contracting the dermal collagen, and allowing the skin to reepithelialize in a more uniform manner. The great advantage of the laser is that it can be controlled precisely to remove only these layers of tissue, while preserving the underlying reticular dermis, which contains important epithelial adnexal structures (eg, hair follicles, sebaceous glands), which can provide epithelium and aid in internal healing of the wound. Healing occurs rapidly without scarring, even if the entire epidermis of the face is removed. Examples of cosmetic and facial dermatologic uses of the laser include the following:

Epidermal nevi
Tissue tags

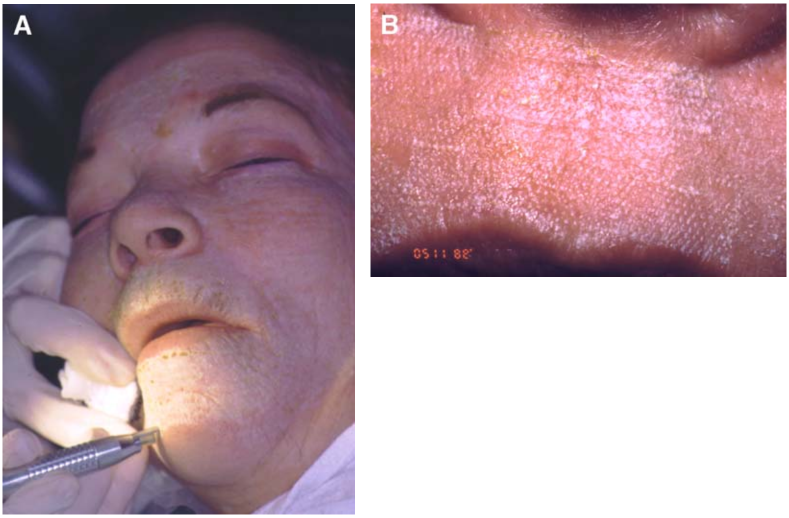

Fig. 13. Full-face cosmetic skin resurfacing using a rotating scanner. (*A*) The scanner provides an increased spot size for larger areas and decreases surgical time. (*B*) Close-up view shows dehydrated tissue that is wiped off with wet gauze in the same manner as char layer is removed.

Lentigines
Seborrheic keratosis
Superficial pigmentation
Solar cheilitis
Skin wrinkles
Blepharoplasty
Endoscopic brow lift
Scar revision
Melasma

The technical change in laser surgery that made cosmetic skin resurfacing possible is the concept of delivering shorter pulse duration energy, such as superpulse or free-running pulse. This concept ensures that the laser energy does not dwell on the tissue for greater than the thermal relaxation time of the target tissue (~700–1000 μs in this case). Tissue removal occurs with minimal thermal damage to the underlying reticular dermis and the adnexal structures. Although the CO_2 laser traditionally has been used for this purpose, the Er:YAG is becoming popular as an alternative and companion to the CO_2 laser.

Laser-assisted uvulopalatoplasty

Since Kamami [38] first described the procedure in 1990, LAUP has become an attractive alternative to traditional scalpel uvulopalatopharyngoplasty (UPPP) for treatment of snoring and mild sleep-disordered

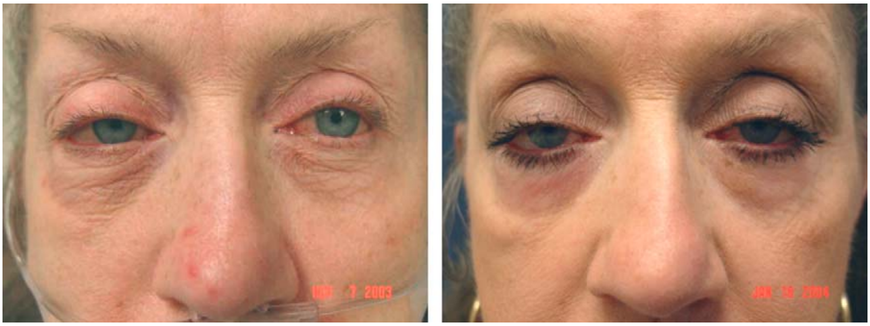

Fig. 14. Before and after comparison of a patient following periorbital cosmetic skin resurfacing. At approximately 8 weeks postoperatively, there is still some resolving erythema.

breathing. The procedure is designed to enlarge the posterior airspace and reduce or eliminate pharyngeal obstruction during sleep. Although primarily indicated for the treatment of snoring, LAUP has been used by many clinicians as a component of treatment protocols for some cases of obstructive sleep apnea syndrome (OSAS).

Snoring is a common social problem, affecting approximately 20% to 30% of the adult population, and has been associated with morning fatigue, restless sleep, daytime somnolence, and hypoxemia [39]. In addition to the social implications, snoring can be a risk factor for hypertension, angina pectoris, cerebral infarction, pulmonary hypertension, and congestive heart failure. A significant percentage of snorers also have associated OSAS, marked by repeated episodes of apnea and hypopnea during sleep secondary to collapse of the upper airway despite respiratory effort. Serious medical consequences of OSAS include cardiac arrhythmias, myocardial infarction, systemic and pulmonary hypertension, and an increase in the risk of motor vehicle accidents.

The most commonly performed treatment of patients with these sleep-disordered breathing problems has been UPPP. This procedure is fraught with complications, however, including severe pain, hemorrhage, transient nasal regurgitation, permanent velopharyngeal insufficiency, and nasopharyngeal stenosis [40]. LAUP offers significant advantages over traditional UPPP. Because the procedure can be performed with local anesthesia, many patients who present with major surgical and anesthesia-related risks can benefit from LAUP. By using a laser in lieu of a scalpel or electrocautery, there is less postoperative swelling with minimal bleeding from the highly vascular palatal mucosa. Troell et al [41] found that the LAUP technique caused less discomfort overall compared with the UPPP. The authors believed this to be a result of the lower temperatures necessary to ablate tissue with laser energy than with electrocautery.

Despite the advantages and low morbidity associated with LAUP, the surgeon must be thorough and systematic when evaluating patients with sleep-disordered breathing. It is imperative that a complete workup of the patient be done encompassing history and physical examination (including nasopharyngoscopy); often a polysomnogram needs to be performed before initiating treatment. Patients with retropalatal obstruction are the best candidates for successful LAUP [42]. The procedure can be done in the office under local anesthesia or intravenous sedation and generally takes less than 30 minutes. A special laser handpiece with a protective backstop should be used to prevent direct laser effects on the posterior pharyngeal wall (Fig. 15) [43].

After the administration of local anesthesia, the procedure begins with two vertical through-and-through incisions of the soft palate adjacent to the uvula and extending a few millimeters short of the levator palatinus muscle insertion (determined by phonation or gagging). Using a standard incisional technique, the backstop is placed behind the soft palate, and the vertical cuts are made inferiorly to superiorly. A relatively high-power density (often 15–20 W with a 0.1–0.4 mm spot size) commonly is used to shorten the procedure time. Care is taken to prevent thermal conduction from the backstop to the pharyngeal wall.

The laser is turned sideways, and the uvula and soft palate outlined by the vertical trenches are removed using the same incisional technique. Finally, the laser is turned laterally, and the lateral soft palate and tonsillar pillars can be excised or ablated as needed to maximize the airway opening. The patient can be discharged to return home or even to work directly from the office. Recovery is complicated only by a severe sore throat that lasts 7 to 10 days.

Some patients require an additional treatment session aimed at further palatal elevation, and this typically is performed at 2 to 3 months, if needed. As the surgeon becomes more experienced with this procedure, a "one-session" LAUP procedure is often possible. Remacle et al [44] reported that one surgical stage is sufficient as long as the palatal musculature is respected. To allow for proper clearing of secretions from the posterior pharyngeal wall, these investigators recommended that a minimum of 4 to 5 mm of uvula remain on completion of the procedure; however, this is not universally agreed on. In a prospective, randomized study of 95 snoring patients treated with varying lengths of soft palate incisions and percentage of uvula excisions, Kotecha et al [45] suggested that a vertical incision size of 25% of the distance from the free edge of the soft palate to the soft and hard palate junction yields the best postoperative results with minimal complications. This study also showed that a 50% excision of the uvula was most beneficial. The results were confirmed via postoperative evaluation, including polysomnography.

Reports on the efficacy of LAUP for snoring have reported encouraging short-term results with clinical success rates ranging from 70% to 95% [46–48]. Few studies have analyzed outcome assessment beyond 2 years postoperatively, however. Some studies, albeit with small patient samples, suggest that there is a qualitative and quantitative subjective decline in snoring improvement over time. The reason for this is multifactorial, with

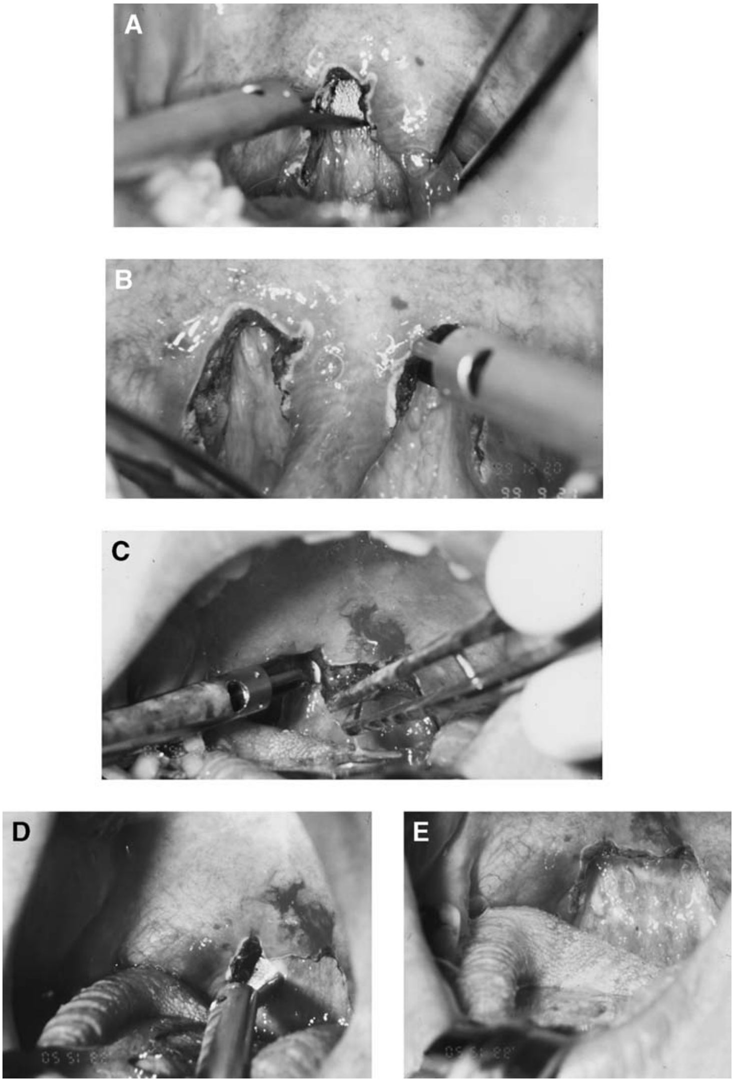

Fig. 15. Laser-assisted uvulopalatoplasty. (*A*) Backstop handpiece used to incise soft palate without damaging posterior pharyngeal wall. (*B*) Incision of side of palate adjacent to uvula. (*C*) Horizontal excision of uvula and portion of soft palate. (*D*) Excision of strip of tonsillar pillar laterally using the laser handpiece turned sideways. (*E*) View after completion of procedure. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:868; with permission.)

weight fluctuation and increasing body mass index as probable causes. Nevertheless, a realistic informed consent before the recommendation of LAUP for long-term cure of snoring should be discussed before initiating surgical management.

The role of LAUP for the treatment of patients with OSAS is poorly defined, but more recently LAUP has gained limited acceptance as an alternative to UPPP for the treatment of patients with retropalatal obstruction as the primary cause. Although the published literature presents conflicting reports of LAUP efficacy, variations in technique have been shown to be promising. A technique described by Kern et al [49] included adjunctive tonsillectomy with LAUP for the treatment of moderate and severe OSAS. The results of this study indicated a surgical response rate that is comparable with data using UPPP with fewer complications. The importance of proper patient selection cannot be overemphasized. Patients with milder OSAS (respiratory disturbance index <30) and site-specific disease are more amenable to surgical treatment with LAUP. As several studies suggest, it generally is accepted that the LAUP technique alone or in association with other procedures is less effective in cases of severe OSAS and seems better indicated for patients with minor and moderate disease.

Dental implants

The use of endosseous implants in edentulous sites has increased dramatically and now is regarded as an essential conservative option for tooth replacement. Lasers are proving to be a valuable tool, with multiple applications for implant surgery. Although some studies have suggested the use of lasers for preparing the hard tissue for implant placement [50], applications of the laser for implant surgery have focused primarily on soft tissue revision, second-stage surgery, decontamination of implant surfaces, and treatment of peri-implantitis. The unique properties of the laser offer significant advantages for soft tissue management surrounding dental implants, including improved control of possible hemorrhage, less mechanical trauma to the soft and hard tissues, prevention of local infection, less postoperative inflammation and pain, improved healing, and decreased risk of postoperative bacteremia.

As the use of lasers in implant dentistry has grown, much concern has been raised regarding the hazards of laser applications. When using the laser, some of the energy may be absorbed or transferred to the implant, causing deleterious effects. When Er:YAG and CO_2 lasers are applied to metal, energy reflection occurs, leaving the implant surface intact without significant alterations. Many authors have found the Nd:YAG laser to cause a considerable increase in irradiated implant temperature secondary to energy absorption by the titanium metal. Kreisler et al [51] assessed the effects on different implant surfaces of Nd:YAG, Ho:YAG, Er:YAG, and CO_2 lasers and concluded that the first two types should not be used for implant surgery because they harm the surface of all endosseous implants. The CO_2 and Er:YAG lasers can be used only at low power because they can affect the implant surface. The 810-nm GaAlAs diode laser seems to be safe as far as possible surface alterations are concerned.

Thermal damage also has been implicated in implant failures with adjunctive laser surgery. Temperature increases of 47°C to 50°C have been shown to induce tissue damage in the bone leading to necrosis and failed osseointegration. To this end, many studies have analyzed the thermal effects generated by different laser systems on osseous regeneration. Barak et al [52] have shown that the temperature rise resulting from CO_2 laser application to different implant types varies according to the laser power rating and exposure time. They found no thermal damage when operating at a continuous 4 W for a period of less than 5 seconds. The risk of altering osseointegration was minimal. Similar studies using the Er:YAG with pulse energies of 60 to 120 mJ found no evidence of heat generation in the peri-implant bone. Water cooling is not necessary when irradiating ailing implants with an Er:YAG laser [53].

In second-stage implant surgery, bone often is found above the healing cap or at the implant margins. Traditionally, this tissue has been removed using a combination of rotary or manual instruments. In either case, extreme caution must be used to prevent damage to the implant surface. This situation has led to the advent of lasers for implant uncoverings. The CO_2 and Er:YAG lasers are most appropriate for this purpose. The Nd:YAG laser should be avoided in soft tissue surgery surrounding dental implants because it has been found to cause temperature increases in the surrounding bone. The CO_2 laser is more useful for soft tissue surgery than for bone surgery because of its shallow depth of penetration. The Er:YAG laser is particularly advantageous in these situations because it can eliminate soft tissue and ablate bone without damaging the implant surface. Using an Er:YAG laser for second-stage implant surgery, Arnabat-Dominguez et al [54] caused less surgical trauma, obviated the need for local anesthesia, and minimized postoperative pain. The indication for lasers in second stage implant surgery is limited, however, by the need to maintain gingival keratinization and by esthetic requirements that involve mucoperiosteal flaps or gingival tissue enhancement.

Peri-implant infection results in inflammation of the surrounding soft tissues and can induce a breakdown of the implant-supporting bone. Implant maintenance is crucial for long-term implant prognosis. Several treatment regimens have been proposed for cleaning and decontamination of implant surfaces, including plastic curets, bactericidal chemicals, and local or systemic antibiotics. Various laser systems are now used in the treatment of peri-implantitis, but their application has been limited to surface decontamination before surgical repair or regeneration [55]. The CO_2, Er:YAG, and diode lasers have been shown to be safe and effective for treating peri-implantitis [56]. Care must be taken when using the CO_2 and

Er:YAG lasers to avoid using high powers that can cause implant damage. The diode laser, with a clinic setting of 1 W continuously for a maximum of 20 seconds, is recommended and has been shown to have no pathologic effects on the soft and hard tissues and the implant surface.

Temporomandibular joint surgery

Arthroscopic surgery has become the primary treatment of choice for surgical internal derangements of the TMJ. Lasers have several advantages compared with conventional cutting instrumentation and techniques. Diseased tissues can be removed without mechanical contact, significantly decreasing trauma to the articular cartilage and synovial surfaces. Lasers also provide hemostasis within the joint without causing thermal damage. In addition, the technical precision of laser surgery is far superior and eliminates the possibility of instrument breakage and retrieval [57].

The water-filled environment of the joint precludes the use of the CO_2 and the Er:YAG laser because the synovial fluid would absorb the laser energy before contact with the target tissues of the joint itself. Using a laser such as a Ho:YAG enables the surgeon to perform all the techniques capable with the CO_2 laser, but because of its limited absorption by water, it transmits through fluids and can be used directly within the fluid-filled joint space (Fig. 16). The Ho:YAG laser vastly improves the ability to remove and sculpt diseased tissues compared with mechanical instrumentation [58]. The small size of the tip and the easily manipulated fiberoptic handpiece reduce operating time and allow access to all recesses within the TMJ. It has been established that with a power output of 0.8 J and a pulse rate of 10 Hz (8 W), tissues are efficiently ablated without creating excessive zones of thermal damage. Using this technique, such procedures as diskectomy, diskoplasty, synovectomy, hemostasis, posterior attachment contraction, eminectomy,

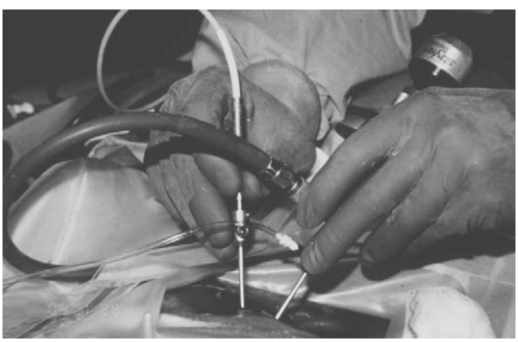

Fig. 16. Temporomandibular joint arthroscopy using a holmium:YAG laser. Separate ports are required to provide the surgeon with visibility of the laser tip during use. (*From* Strauss R. Lasers in oral and maxillofacial surgery. Dent Clin North Am 2000;44:872; with permission.)

and débridement of fibrous ankylosis can be performed on an outpatient basis through two incisions less than 2 mm each.

Laser scar revision

Oral and maxillofacial surgeons frequently are faced with the management of cutaneous injuries causing scar formation. Many patients seek treatment for esthetic and functional improvement. Despite adequate initial management of traumatic maxillofacial cutaneous injuries, scarring is a natural part of the healing response. Management of these injuries depends on the surgeon's ability to hide scars and make them as inconspicuous as possible.

There are numerous techniques described in the literature to treat facial scars. Surgical excision, skin grafting, dermabrasion, corticosteroid injections, radiation therapy, and cryotherapy all have been used with varying degrees of success. Advances in laser technology have led to increasing use of pulsed-dye lasers (PDLs), Er:YAG lasers, and CO_2 lasers. The choice of laser is influenced by the qualities of the scar, including color and texture, and the timing and types of previous treatments.

PDLs have proved to be effective for treatment of hypertrophic scars and show striking improvements in scar textures [59]. The 585-nm PDL specifically targets blood vessels within the scar tissue, leading to fibroblast proliferation and decreased collagen production. PDLs often are referred to as vascular lasers because they have hemoglobin as their chromophore and penetrate the epidermis without deepithelialization. By reducing scar tissue erythema and inducing collagen remodeling to flatten and soften scars, the PDL is indicated for erythematous and hypertrophic scars of the maxillofacial region. Revision usually is performed on an outpatient basis without anesthesia. A lidocaine-containing cream (eg, EMLA cream) can be used as a topical anesthetic 30 to 60 minutes before initiating treatment. Most lesions show an 80% improvement after two PDL treatments. A period of 6 to 8 weeks between treatments is recommended to allow healing. A topical antibiotic or healing ointment is recommended for the first few postoperative days. Strict sun avoidance should be practiced to avoid stimulating pigment production in these areas.

Atrophic scars are best treated by Er:YAG and CO_2 lasers. As previously discussed, these lasers ablate superficial tissues and cause deepithelialization using water as the target chromophore. The goal of treatment is to soften depressions in the skin and stimulate neocollagenesis to refill residual defects. Before initiating treatment, the number and location of facial scars must be considered. Spot resurfacing is indicated when few atrophic scars exist. The entire facial cosmetic unit should be treated, however, for more widely distributed scars. Most atrophic scars require a minimum of two to three passes. Significant side effects and complications that can occur with laser scar revision should be discussed with the patient preoperatively. During the immediate postoperative course, the patient should expect intense erythema, edema, and serous discharge. Other possible complications include infection (viral and bacterial), milia, hyperpigmentation, and delayed-onset hypopigmentation. It is incumbent on the surgeon to understand the physics of laser surgery to ensure that these risks are minimized.

Summary

Lasers have quickly become indispensable in OMS as a modality for the treatment of soft tissue surgery. As laser technology has advanced, so too has their use within the expanding scope of OMS. Lasers not only allow surgeons to enhance current surgical options for treatment, but also have contributed to the evolution of a variety of new procedures that are now commonplace in OMS.

Many new laser systems are on the market today, each with wavelengths and features that make them unique. Although these new systems make some procedures easier, it has become essential for the laser surgeon to rely on the basic principles of laser physics to use them in a safe and efficient manner. The incorporation of lasers into the practice of OMS has led to exciting advances in surgical therapy and improved patient care. Advances in laser technology undoubtedly will yield new procedures and have a major role in the future of minimally invasive surgery.

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