4B

Radiowave Surgery in Oral and Maxillofacial Surgery

Four-megahertz radiowave surgery is a new technology with many applications for our specialty, including dentoalveolar, orthognathics, and cosmetic facial surgery. In essence, radiowave surgery can be used for virtually any application for which a scalpel is traditionally used. In fact, when one considers the cost savings of not having to buy scalpel blades and the safety features of not getting stuck or cut, a practitioner could probably purchase a radiowave system for what was traditionally spent on blades.

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Prehistoric humans used sharpened objects to incise soft tissue, and for centuries, open fires and red-hot instruments were used to cauterize and sear bleeding tissue. Albeit refined, the same technology persisted until the discovery of electricity. Radiowave surgery has been shown to be an improved modality in soft tissue surgery.[1–7] The use of electricity for surgical incision and coagulation dates back to its discovery. Before raw alternating current could be used for surgery, a generator was required that could produce the high-frequency current. This was developed in 1889 by Thompson, who noted heat in his wrists when immersed in saline solution while passing a current through his hands.[8] In 1891, d'Arsonval showed that electric currents with frequencies of greater than 10,000 Hz failed to cause neuromuscular stimulation and the associated tetanus response.[9,10] Oudin modified d'Arsonval's equipment in the 1890s to generate a spray of sparks that caused superficial tissue destruction.[11] Work continued at refining the use of electrical current, and in the late 1890s and early 1900s, the use of electrodes was conceived to concentrate the density of the current. The use of electrodes enabled control of the spark and was successfully used to
2
treat lesions and reported in 1900.[12] In 1907, de Keating-Hart and Pozzi introduced the term *fulguration* (from the Latin word *fulgur*, meaning lightning). This referred to the superficial carbonization resulting when the spark from an Oudin coil was used to treat skin.[11] In 1909, Doyen introduced the term *electrocoagulation* (from the Latin word *coagulare*, meaning to curdle).[13] This was used to describe the tissue response when touched by an electrode while an indifferent electrode (antenna) was attached to the patient. The indifferent electrode allowed for the removal of the current entering the patient and channeled the electricity back into the electrosurgical unit. This prevented the buildup of static electricity so that electrical shocks were not caused to the patient or the operator. This recycling of current allowed the use of lower voltages with increased amperages and along with the biterminal electrode arrangement allowed for deeper tissue coagulation compared with previous surface carbonization.[11] This circuitry set the stage for the device configurations used today.

In 1923, Wyeth used electrosurgery for actually cutting tissues instead of merely charring or desiccating them. He developed an apparatus called the endotherm knife,[14] which not only cut, it also sealed off smaller blood and lymphatic vessels.

William Bovie, a Harvard physicist, developed a practical electrosurgical device in 1928 that offered both cutting and coagulation modes,[15] which led to the modern machines used in today's hospital operating rooms.

Radiowave surgery is not "electrosurgery." Dr. Alan Ellman, a practicing dentist, patented the 4.0 MHz wavelength radiowave surgical system in 1999. There are significant differences between electorsurgery and radiowave surgery in both the mechanisms and the tissue response.

Radiowave Surgery Principles

The optimum radiosurgery wave is a frequency of 4.0 MHz, which is similar to the frequency of marine band radios.[16,17] Figure 4-7 shows the range of frequencies used in different applications.

Radiofrequency machines operate by using a 60-cycle AC electrical (ordinary household) current, which is converted to a DC current by a rectifier. The DC current then passes through a coil or rectifier, which actually generates the radio waves. These radiofrequency waves pass through a high-frequency waveform adaptor, which can modify the shape and magnitude of the radio waves, thus producing the desired waveforms used in surgery. The Ellman Surgitron IEC 2 (Ellman International, Inc., Oceanside, NY) is representative of the latest dual-frequency radiowave technology and is discussed in this article (Figure 4-8).

The radio waves are transferred from the electrode tip to the patient and are returned to the machine by a neutral antenna plate. The neutral electrode plate does not need to contact bare skin. Impedance to the passage of the radio waves through the tissue generates heat within the cells, which boils intracellular tissue water, creating steam, and the resulting vaporization results in either cutting or coagulation of tissue.[18] The steam generated from the energy transfer causes the cell inner pressure to increase from the inside out (explosion). This phenomenon is referred to as cellular volatilization.[19] This frequency does not cause the actual electrode to heat but precisely delivers the energy. Frequencies below 3 MHz will heat or melt the electrode. Proprietary surgical tungsten electrodes (Ellman Empire Micro Needle, Ellman International, Inc.) are produced, which resist damage and retain their fine tip. These electrodes are matched to the 4 MHz for precise cutting.

Four-megahertz radiofrequency surgery should not be confused with conventional electrosurgery, electrocautery, or diathermy surgery. With radiofrequency surgery, no electrical contact needs to be made between the patient and the Teflon-coated neutral antenna (see Figure 4-8). Unlike the electrocautery (or diathermy machines, as they are referred to in the United Kingdom), the radiofrequency electrode does not provide resistance and remains cold. The tissue provides the resistance. A cautery machine, however, uses lower frequencies and the passage of current through the electrode filament, which provides the resistance and is heated. In the purest sense, this is similar to a soldering iron or wood-burning tip. This arrangement provides significant lateral tissue damage. Since radiofrequency generates less heat than conventional cautery, less

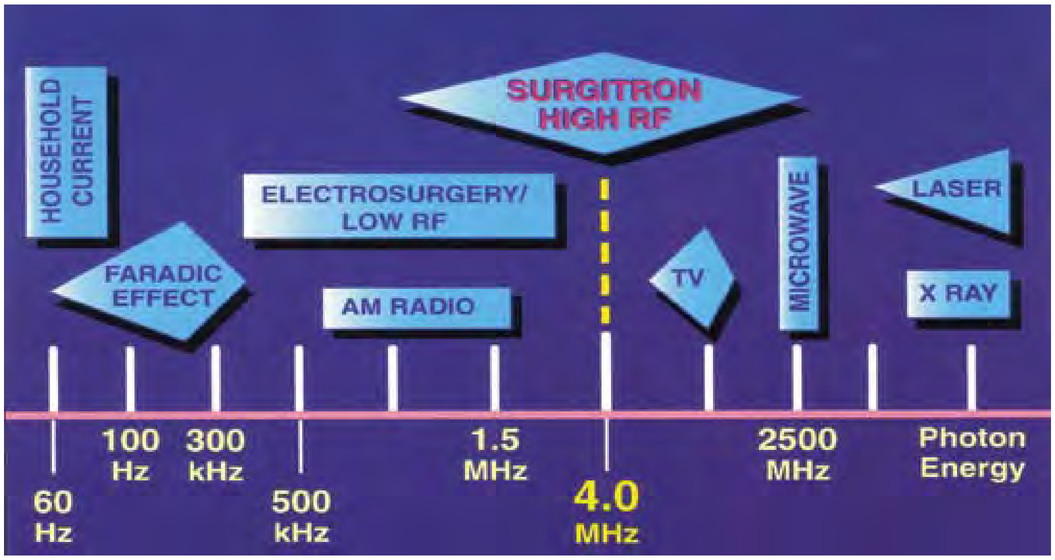
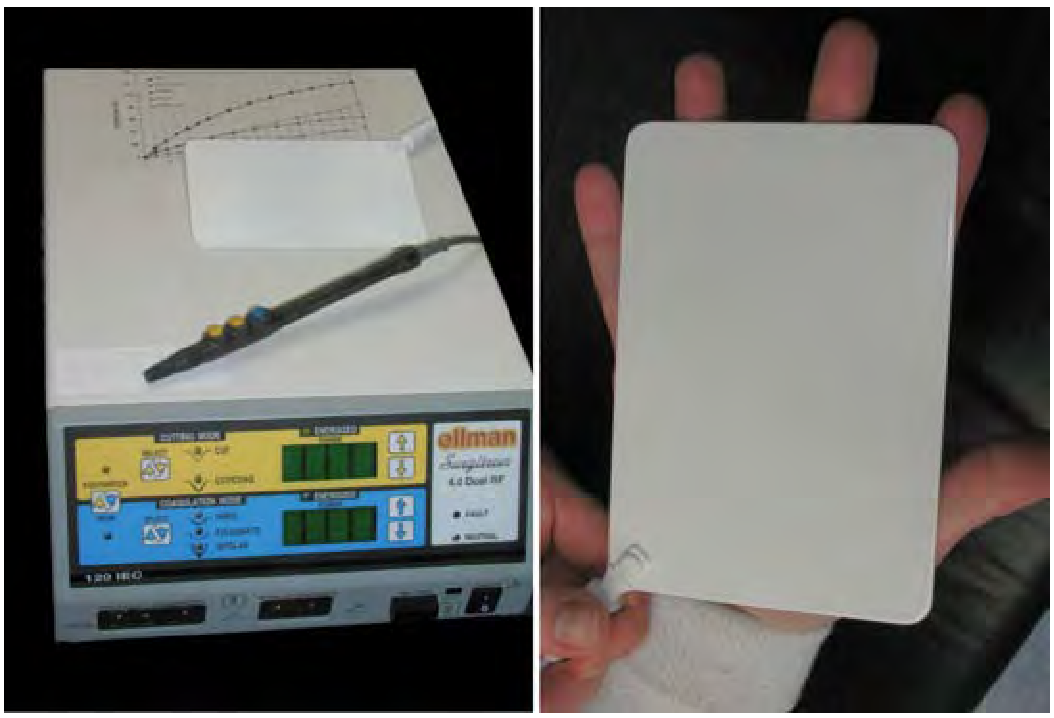


FIGURE 4-7 The 4.0 MHz wavelength of radiofrequency is comparable to that of a marine band radio.



3 **FIGURE 4-8** The Ellman dual-frequency Surgitron IEC II has notable advantages over conventional electrosurgery and is well suited for cosmetic surgery applications.

collateral damage is seen and therefore faster healing. Bridenstine found biopsies done with radiofrequency incision to have thermal damage zones of 75 microns, which is comparable to the CO_2 laser.[1] Other studies have confirmed minimal tissue damage and comparable biopsy margins with scalpel excision.[20–22]

The high-frequency radiowaves are modified by filtering and rectification to produce four distinct waveforms:

1. *Cutting.* This waveform consists of 90% cutting and 10% coagulation. This is a fully filtered waveform for microsmooth cutting with little tissue damage and concomitant coagulation. Histologically, this is the fastest healing waveform.
4 2. *Cutting/coagulation.* This waveform consists of 50% cutting and 50% coagulation. It is designed for equal amounts of cutting and coagulation and is especially useful in vascular areas while maintaining minimal amounts of lateral heat and tissue damage.
3. *Hemostasis.* This waveform consists of 10% cutting and 90% coagulation and is designed for direct and indirect hemostasis techniques. Its use does not create charring or necrosis. This waveform can also be used to perform unipolar and bipolar coagulation.
4. *Fulguration (spark gap).* This waveform is designed to generate a shower of sparks, which provides maximum char and necrosis. High lateral heat and maximum hemostasis are produced with the fulgurating waveform, which is used for intentional destruction of diseased tissue.

To use the optimum characteristics of radiowave surgery, adjacent tissue damage must be limited. Time of tissue contact, power intensity, waveform, and frequency of application are the variables that contribute to the lateral thermal tissue destruction, as illustrated in the formula below:

$$LH = \frac{T \times I \times W \times S}{F}$$

where LH is lateral that, T is time, I is power intensity, W is waveform, S is surface area, and F is frequency. 5

The amount of time that the electrode contacts the tissue is obviously paramount to prevent excessive lateral tissue damage. The faster the electrode passage, the less tissue damage is produced. A rate of 7 mm/s was proposed by Kalwarf and colleagues.[20] A metaphor to this principle would be using a clothes iron. If you move the iron over a shirt and keep moving, you will have even heat distribution, but if you leave the iron in one spot for too long, you will have a scorch in that area owing to excess heat.

The power intensity is also critical for proper technique. Optimum intensity will allow a smooth and effortless passage of the active electrode through the tissue. Too low of a power setting will cause sticking of the tissue and offer resistance or dragging. An excessive power setting will carbonize the tissue and cause sparking.

The frequency setting also affects the amount of lateral heat generation, as well as the healing results. A lower frequency (traditional electrosurgery) generates a less efficient cut and produces more heat, additional postoperative discomfort, and increased healing time. The optimum frequency for minimum tissue destruction is 4.0 MHz.

The waveform contributes to lateral heat and treatment destruction as well. The fully filtered current produces the least heat, whereas the fulguration waveform generates the greatest amount of heat.

Finally, electrode size is another significant variable in the formula of heat generation. A large electrode tip requires more power and therefore produces more lateral heat when compared with a thinner electrode.

Passive Electrode

The passive electrode is also called an antenna, a passive antenna, a neutral antenna plate, or an indifferent electrode. This plate acts like a radio antenna by attracting the radio waves emitted from the machine and channels the energy back into the unit. The passive electrode is coated with a Teflon material to eliminate the possibility of burns or shocks (see Figure 4-8). Since the passive electrode is not technically a grounding electrode, it does not need to contact bare skin and may be placed over clothing. Some practitioners merely place the passive electrode under the cushion of the surgical table under the patient's shoulder. The closer the passive electrode to the surgical site, the less power is required; thus, there is less chance of lateral thermal damage. Placing the antenna close to the surgical site will provide better reception of the surgical antenna, just as extending the antenna on a cellular telephone increases the reception signal. The passive electrode plate is usually not placed under the head as there is less surface area, so placing it under the shoulder is adequate. The passive electrode is not necessary when using the bipolar mode.

Active Electrode

The active electrode is the energized tip of the radiowave system. The microtip is used to direct the radio waves through the tissue to make the incision. The radio waves cause the incision, not the electrode tip. This is one of the main differences between radiowave surgery and "electrosurgery." The active electrode tip can be bent to better navigate anatomic surfaces and angles. Many different types and configurations of electrode tips are available. Straight electrode tips are the most frequently used for tissue incision. Tungsten microneedles, such as the Empire Micro Needle, have become very popular for ultrafine incisions, such as blepharoplasty and lesion removal. These tips are very fine and long-lasting.

Loop electrodes are also popular for the excision of pedunculated lesions, and diamond-shaped electrodes are available that enable an elliptical incision for better closure. The Ellman Vari-Tip electrode consists of a fine wire that passes through a sleeve. The wire can be extended or retracted to adjust for the depth of the cut. In addition, the small diameter of the Vari-Tip requires reduced power settings and produces little collateral tissue heating. I prefer this tip for rhytidectomy of a fine skin incision. Although the pointed microelectrodes are well suited for fine incision, they are conical in cross section, and the deeper they pass through the skin, the wider the incision, whereas a fine wire has the same diameter throughout its length.

FIGURE 4-9 The Ellman Empire tungsten electrode.

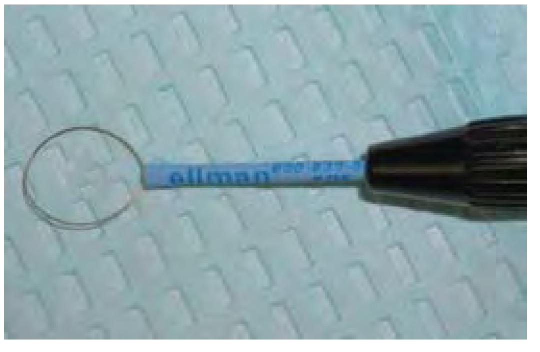


FIGURE 4-10 Loop electrodes can be bent to accommodate a hard to reach place.

Ball and flat cylindrical electrodes are used for coagulation of bleeding tissue and vessels as well as ablation of soft tissue lesions, such as nevi and keratoses. Other specialized electrodes are available for endoscopic brow-lift procedures, palatopharyngoplasty, tympanoplasty, palatal graft harvesting, tonsil and turbinate shrinkage, depilation, and ablation of telangiectasias.

Advantages of Radiowave Surgery

Multiple advantages exist with radiowave surgery when compared with scalpel incision, electrocautery, and laser soft tissue incision and coagulation (Table 4-1).

The most significant advantages of radiosurgery are simultaneous cutting and coagulation without significant lateral tissue damage. This reduced heat promotes less postsurgical pain and faster healing.[1–7] Another advantage is a pressureless incision. Since the radiowave electrode channels the current to the tissue and does not cut by heat, it is merely glided through the tissue. Owing to the increased control and tactile sensitivity, the incision is more precise. This is especially evident when cutting very thin or mobile tissues, such as eyelid skin, oral mucosa, or earlobes. Typically, scalpel incision in these areas requires pressure and causes dragging or bunching of the tissue.

Table 4-1 Advantages of Radiowave Surgery

Incision without applying pressure (pressureless incision)
Simultaneous hemostasis
Bacteria-free incision
Artifact reduction in biopsy compared with electrocautery
The ability to bend or shape the cutting electrode for anatomic variation or working in cavities
Produces scarring equal to or better than scalpel or laser incisions
Pays for itself in not having to purchase scalpel blades
No accidental scalpel injuries
No dealing with dull scalpel blades
Minimal safety precautions when compared with lasers

Biopsy artifact damage is also reduced with radiowave surgery. Turner and colleagues showed that when compared with CO_2 and neodymium: yttrium-aluminum-garnet lasers, there is significantly less tissue damage, which can affect the diagnostic ability of the pathologist.[7] They also reported the pure cutting waveform of radiowave surgery to approach the quality of cold knife excision.

A bacteria-free incision is also possible with the radiowave electrode. Although the electrode does not heat, the resistance of the soft tissue causes a release of energy and produces steam within the cells, which causes vaporization and sterilization. In addition, the electrode may be "steam cleaned" by holding the electrode between the layers of moistened gauze and activating the unit. This causes the electrode to spark and produce steam, which is self-cleansing. This also allows the electrode to be easily cleaned of debris. Unlike the electrocautery tip, which is cleaned with abrasives, the surgical debris may be easily removed by passing the electrode tip through wet gauze and activating the current.

Clinical Applications in Cosmetic Facial Surgery

Four-megahertz radiowave surgery is a technological advance over traditional electrosurgery. Radiowave surgical technique can be applied to virtually any incisional situation in which one would traditionally use a scalpel, scissors, and, in many cases, laser.

Radiowave Blepharoplasty

One of the most useful indications of radiowave surgery is cosmetic blepharoplasty. This modality produces scars consistent with scalpel incision but produces significantly more hemostasis. In addition, the ability to cut the thin tissues of the eyelid without pressure or tissue drag is impressive.

The CO_2 laser is an excellent tool for cosmetic blepharoplasty but is not accessible to many practitioners. In addition, the Ellman radiowave surgery unit is portable and does not require the doctor, patient, and staff safety precautions
7 that the laser does. Welchs showed histologically that the 4.0 MHz radiowave surgery causes less thermal damage on resected periorbital fat pads when compared with the CO_2 laser.[7]

The surgical technique for blepharoplasty involves the usual markings and local anesthetic injections. The skin incision is performed with the Empire Micro Needle with a pure cutting waveform (90% cutting, 10% coagulation). Skin and muscle bleeders are controlled by grasping the area with small forceps and touching the radiowave tip to the instrument. After skin excision, the pure coagulation setting is used and a strip of orbicularis muscle is excised and coagulated in the same manner. The orbital septum is opened, and the fat pads are identified and gently elevated with forceps and their base cauterized with the Empire Micro Needle. No clamping is necessary as the cutting and coagulation with the radiowave electrode are excellent. I have performed over 100 radiowave blepharoplasties with excellent hemostasis. 8

I have performed side-by-side comparisons with 4.0 MHz radiowave surgery with the CO_2 laser for upper blepharoplasty. Figure 4-13 shows

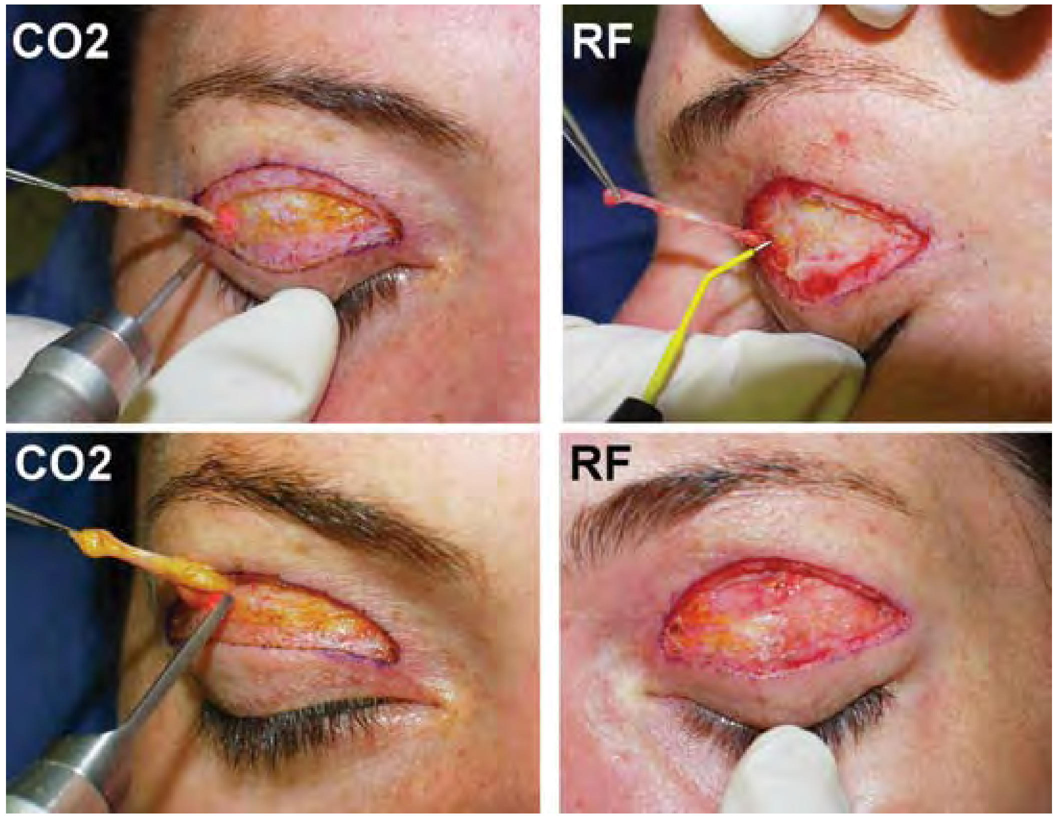


FIGURE 4-12 The equally bloodless surgical field when removing muscle and fat from the upper eyelids.

FIGURE 4-11 The images on the *left* show the CO_2 laser and the bloodless skin incision and excision. The images on the *right* show the same bloodless surgery using an Ellman Empire Micro Needle with a pure cutting mode.

FIGURE 4-13 A 12-month postoperative scar when the right lid was incised with the CO_2 laser and the left lid with the Ellman Radiowave Micro Needle.

blepharoplasty and laser incisions on the same patient. The Empire Micro Needle was used with a pure cutting or a cutting/coagulation (partially rectified) setting on the left eyelid and the Coherent Ultrapulse Encore CO_2 laser was used with an 8-watt continuous-wave setting on the right eyelid. As shown in the images, both modalities provided a virtually bloodless surgical field. In addition, the radiowave surgery side showed a more esthetic scar in the early postoperative period. At the 3-month comparison, the blepharoplasty scars were judged equal by trained observers and the patients.

For lower blepharoplasty, I prefer the transconjunctival approach. The conjunctiva and capsulopalpebral fascia are incised with the Empire Micro Needle and the fat pads are identified and sectioned as previously mentioned using the Empire needle (Figure 4-14), a small ball
9 electrode, or the Ellman #133 electrode.

Radiowave Rhytidectomy

I have used the microneedle or Vari-Tip electrode for pre- and postauricular rhytidectomy incisions on a pure cutting mode and have seen the same healing results as those with scalpel incision (Figure 4-15). In addition, the subcutaneous dissection may be performed with the Empire Micro Needle and hemostasis of the superficial muscular aponeurotic system (SMAS) and muscle is easily performed with the large ball electrode or Ellman bipolar forceps or simple conduction through Addison forceps (Figure 4-16). Having the ability to cut and coagulate without having to pick up a bipolar or similar instrument makes surgery more simple and the field less cluttered. I also use the large ball electrode to shrink irregular contours from plication or lumpy areas of the SMAS. This not only recontours these irregularities, it also causes shrinkage and retraction of the SMAS (Figure 4-17). Finally, greater control and dexterity are available when performing cutbacks and excess skin removal during the face-lift.

Lesion Removal

One of the true strengths of 4.0 MHz radiowave surgery is lesion removal. All practitioners have seen patients present with hypopigmented depressed scars on their face from liquid nitrogen ablation of lesions (Figure 4-18). This all too frequent scenario can be prevented by using 4.0 MHz radiowave surgery to ablate lesions. The #133 electrode is a flat cylinder that can be used at low power with minimal lateral tissue damage. A small ball electrode can also be used for this. In the case of suspicious lesions, the loop electrode may be used at pure cutting power to perform a shave biopsy. This low power does not cause enough artifact to impede histologic analysis. For most lesions, such as nevi and verrucae, the area is anesthetized with local anesthesia and the unit is set to the cutting/coagulation setting. I use surgical loupes and wipe away successive layers of tissue while wiping the char between passes. The lesion is treated just to its base or slightly beyond. It is better to remain conservative and tell the patient that he or she may require a touch-up to remove a remnant lesion than to overtreat and end up with a depression. When treated in this manner, facial lesions leave imperceptible scars, as shown in Figures 4-19 and 4-20.

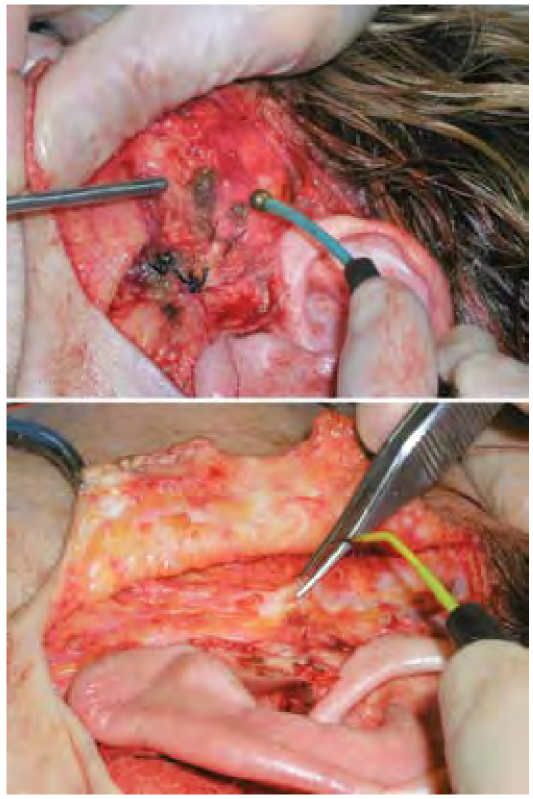


FIGURE 4-16 Coagulation can be performed with the ball electrode or instrument conduction.

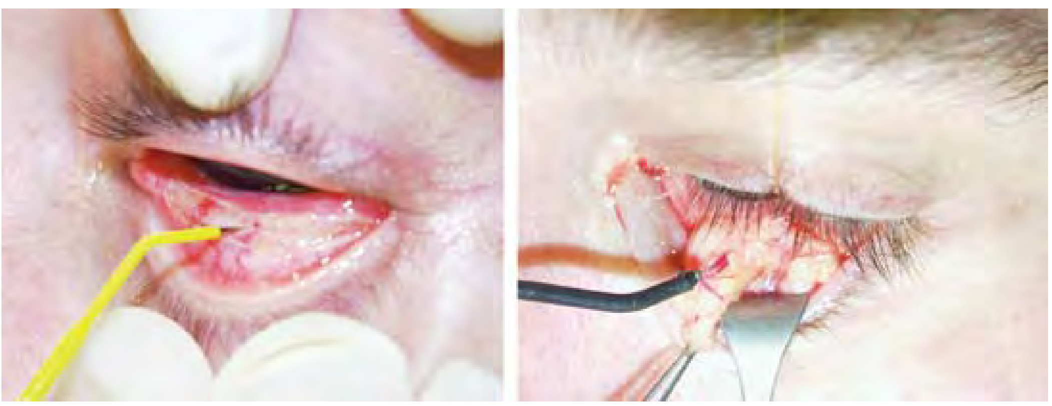


FIGURE 4-14 The conjucntiva and lower lid retractors are incised with a cutting/coagulation current, and the fat pads are contoured with a small ball electrode.

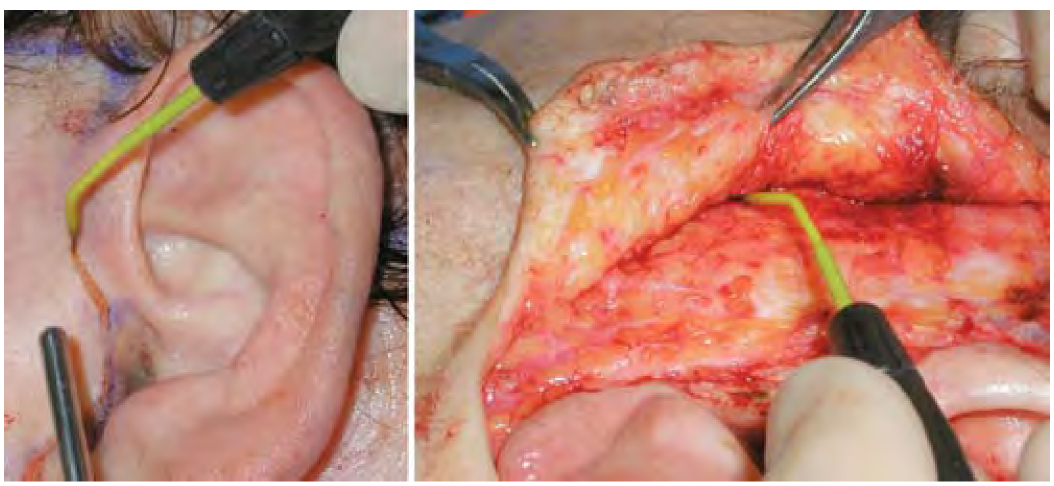


FIGURE 4-15 The Ellman Empire Micro Needle is used to make the skin incision and to dissect the superficial muscular aponeurotic system from the skin flap.

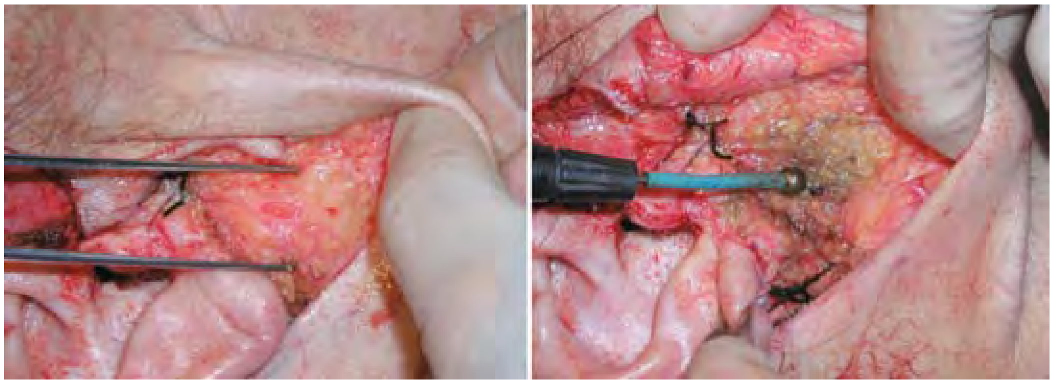


FIGURE 4-17 A preauricular protuberance of the superficial muscular aponeurotic system after placing placation sutures. This mound may be shrunk and flattened by gentle cauterization with the ball electrode.

FIGURE 4-18 Unsightly, depressed, hypopigmented scars frequently result from aggressive lesion ablation techniques, such as liquid nitrogen.

FIGURE 4-19 Multiple nevi and skin tags removed with radiowave surgery.

FIGURE 4-20 Low-power ablation with the Ellman radiowave system and #133 electrode produces minimal lateral tissue damage, thus producing little scarring.

Mobile Tissue Incision

Incising fleshy or mobile tissue is always a challenge. One problem with scalpel incision of fleshy or mobile tissue is that pressure is required, which distorts the tissue and decreases control and precision. The fine-tipped radiowave electrodes, when used at the proper settings, simply glide through the tissue without pressure. This pressureless incision technique is excellent for eyelid tissue, earlobes, and oral mucosa (Figure 4-21).

Specialty Applications

A wide variety of specialized electrodes are available for cosmetic applications.

The Ellman Mucotome is an electrode that is specifically designed for harvesting palatal mucosa (Figure 4-22). These mucosa grafts are used for

FIGURE 4-21 The figure illustrates the ability to make a pressureless incision on mobile tissues for earlobe repair and a lip lesion.

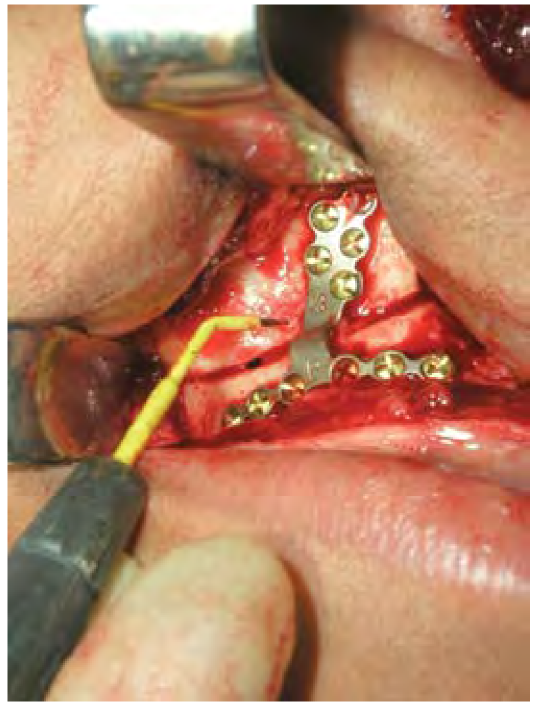


FIGURE 4-24 The Ellman 4.0 MHz radiowave system is well suited for orthognathic and reconstructive procedures.

FIGURE 4-22 Mucotomes are specially designed to harvest palatal grafts of various widths.

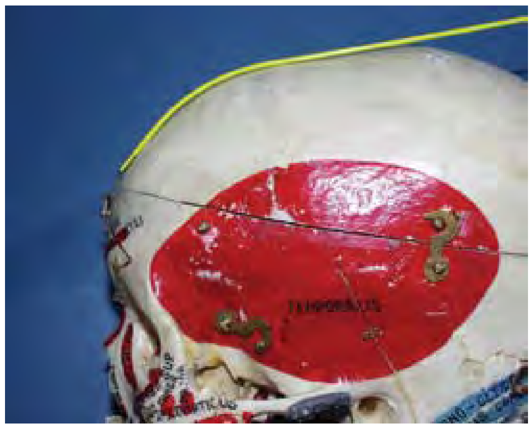


FIGURE 4-23 Many specialty electrodes are available, such as this curved, elongated electrode for endoscopic surgical applications. A curved electrode used for endoscopic brow surgery is shown.

lower eyelid reconstruction and various maxillofacial applications. The Mucotome not only cuts an exact thickness of mucosa, it also simultaneously coagulates the very vascular palatal tissues.

Long contoured electrodes are made for endoscopic brow and forehead lifting, as shown in Figure 4-23.

Again, any procedure that can be performed with a scalpel or electrosurgery can be performed with 4.0 MHz radiowave surgery. I use the Empire Micro Needle for osteotomy incisions.[24] This
10 produces less heat and promotes faster healing.

Hazards, Complications, and Caveats

Like any modality, radiowave surgery presents certain hazards and complications (Jon Garito, Ellmann International, Inc., personal communication).[23,24] Excess lateral tissue damage is proba- 11
bly the most common complication and usually results from operator error (especially novice clinicians) by failing to observe the lateral heat formula discussed previously. Choosing optimal power settings and the correct electrode and ensuring continuous movement, with care not to pass too slowly through the tissue, will prevent increased tissue damage. Understanding the lateral heat formula is critical to an optimum clinical response.

Radiowave surgery should not be used in the presence of flammable anesthetics, liquids, or skin preparations.

Just as the laser plume can be detrimental, radiowave surgery causes tissue vaporization and potential smoke hazard from particulate inhalation. Precautions include careful and controlled smoke plume evacuation and wearing surgical masks rated for microparticle filtration. Although not a complication, inadequate removal of smoke will cause an unpleasant smell throughout the office. If central suction is used, it must be vented to the outside environment otherwise; you are merely redistributing the smoke and smell from one area of the office to another. Special portable evacuation systems are available with viral and activated charcoal filters for both operator and patient safety and comfort.

Radiowave surgery machines may also interfere with other electromedical equipment, such as monitors. In my office, interference with the electrocardiography monitor was corrected by plugging the radiowave machine into a separate circuit from the monitor.

Pacemaker interference has been a major concern in the past but is only a problem with older, nonshielded pacemakers. Most modern pacemakers are shielded from external radiation and therefore are not a problem. Several surgeons exist that themselves have implanted pacemakers and routinely operate with radiowave surgical units without a problem.[23]

The potential exists for interference with implantable cardioverter-defibrillators (ICDs). LeVasseur and colleagues reviewed this topic and made recommendations, including possible deactivation of the ICD prior to surgery.[24] The electromagnetic interference of radiowave surgery may cause the pacemaker to reprogram or otherwise malfunction. In the case of ICDs, the interference may cause the device to fire a cardioversion sequence or reprogram the device. In the case of an ICD discharge, the surgeon is in no danger of electrical shock because the discharge is not transmitted, but it may induce dysrhythmias in the patient.

When radiowave equipment is used in the presence of cardiac pacemakers or defibrillators, a cardiology consultation should be obtained. It is possible that the cardiologist may elect to temporarily inactivate the device during the surgical procedure. Intraoperative cardiac monitoring and emergency cardiac medications should be on hand in the rare case of a cardiac emergency.

Bipolar use of radiowave surgery is safer when operating on pacemakers and ICDs as current is concentrated across the tips rather than through the patient. Short bursts of radiowave surgical energy (less than 5 seconds) are preferable to long electrode activation periods. Pauses between the bursts allow resumption of cardiac rhythm.[24]

Conclusion

Four-megahertz radiowave surgery is a new technology that provides many benefits in cosmetic surgery. Decreased heat and lateral tissue damage, controlled hemostasis, faster healing, adaptability of specialized electrodes, increased tactility, increased operator and patient safety, and cost-effectiveness are notable advantages. All of these advantages are applicable to the very vascular and sometimes mobile tissues in cosmetic facial surgery.

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Chapter 4B: Author Query Form

Chapter: Radiowave Surgery in Oral and Maxillofacial Surgery

1. AU: Need a noun with this.
2. AU: Change as meant?
3. AU: In text, you have 2. Which is correct?
4. AU: Changes okay? Should be consistent.
5. AU: What do you mean?
6. AU: Figs 4-9 and 4-10 need to be cited in text.
7. AU: This is not ref 7. Pls advise.
8. AU: Figs 11 and 12 must be cited in text.
9. AU: Manufacturer and location?
10. AU: Fig 4-24 not cited.
11. AU: Pls provide year.
12. AU: Pls provide inclusive pages.
13. AU: Is the vol missing, or should it be 18?
14. AU: Complete the ref.
15. AU: Should this be Physiol?
16. AU: Which journal is this?
17. AU: What is the article title? What is the journal name?
18. AU: Is this the vol number? If not, pls provide it.