4.0 MHz Radio Wave Applications in Cosmetic Facial Surgery

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Many technological advances have influenced cosmetic facial surgery over the last decade. These advances have helped increase the popularity of cosmetic procedures by enabling faster surgery with less hemorrhage and lateral tissue damage, decreased recovery times, and less postoperative pain. Representative of this new technology is 4.0 MHz radiofrequency surgery, which has been shown to be comparable or superior to scalpel and laser incision modalities. Other advantages include increased hemostasis, pressureless incision, and a wide variety of specialized electrodes. This 4.0 MHz radiofrequency surgery is very different from conventional electrosurgery or cautery; the electrode tip is not heated, and there is no danger of shocking the patient with the ground plate. The use of 4.0 MHz radiofrequency in various cosmetic surgery applications is discussed in this article, along with indications, contraindications, and caveats.

Prehistoric humans used sharpened objects to incise soft tissue, and for centuries bleeding tissue was cauterized and seared with open fires and red-hot instruments. Little changed until the discovery of electricity. Radio waves have 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. For alternating current to be used for surgery, a generator that could produce a high-frequency current was required. This was developed in 1889 by Thompson, who noted heat when his wrists were immersed in saline solution while passing a current through his hands.[8] In 1891, d'Arsonval [9,10] showed that electric currents with frequencies greater than 10,000 Hz failed to cause neuromuscular stimulation and the associated tetanus response. Oudin modified the equipment of d'Arsonval in the 1890s to generate a spray of sparks that caused superficial tissue destruction.[11] Work continued to refine the use of electric currents, and in the late 1890s and early 1900s, electrodes were developed to concentrate the density of the current. Electrodes provided spark control and were reported to successfully treat lesions in 1900.[12] In 1907, de Keating-Hart and Pozzi introduced the term *fulguration* (from the Latin *fulgur*, meaning lightning). This refers to the superficial carbonization that resulted 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] It described the response of the tissue when touched by an electrode while an indifferent electrode (antenna) was attached to the patient. The indifferent electrode channeled the electricity entering the patient back into the electrosurgical unit. This prevented the buildup of static electricity and electric shocks to either 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 deeper tissue coagulation compared with previous surface carbonization.[11] This circuitry set the stage for the device configurations used today.

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

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

There are significant differences between electrosurgery and radio wave surgery in both the mechanisms and tissue response.

Radio Wave Surgery Principles

The optimum radio wave for surgery is a frequency of 4.0 MHz, which is similar to the frequency of marine band radios.[16,17] Figure 1 shows the range of frequencies used in different applications.

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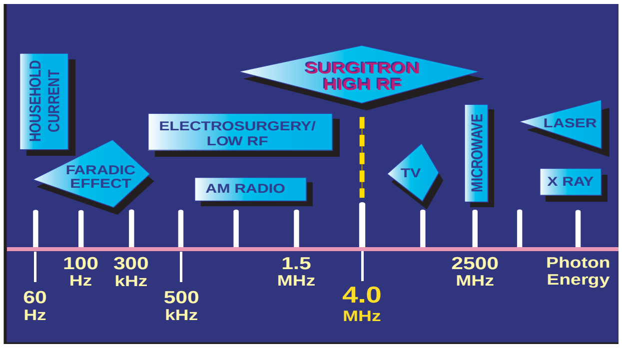

Figure 1. The 4.0 MHz wave length of radiofrequency is comparable to that of a marine band radio.

Radiofrequency machines operate with a 60-cycle, alternating current (AC), or ordinary household current, that is converted to direct current (DC) by a rectifier. The DC then passes through a coil/rectifier that actually generates the radio waves. These radiofrequency waves pass through a high-frequency waveform adaptor that can modify the shape and magnitude of the radio waves, thus producing the desired waveforms used in surgery. An example of the latest dual frequency radio wave technology is the Ellman Surgitron Dual Frequency 4.0 MHz™.

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; the resulting vaporization results in either the cutting or coagulation of tissue.[18] The steam generated from the energy transfer causes the inner pressure of the cell 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 it precisely delivers the energy. Frequencies below 3.0 MHz will heat or melt the electrode. Proprietary surgical tungsten electrodes resist damage and retain their fine tip. These electrodes are matched to the 4.0 MHz for precise cutting.

This 4.0 MHz 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. Unlike electrocautery machines (or diathermy machines as they are referred to in the United Kingdom), the radiofrequency electrode does not provide resistance, and it remains cold. It is the tissue that provides the resistance. A cautery machine, however, uses lower frequencies and the passage of current through the electrode filament, which provides resistance and heats up. In the purest sense, this arrangement is similar to a soldering iron or wood-burning tip, and it causes significant lateral tissue damage. Since radiofrequency generates less heat than conventional cautery, there is less collateral damage, and healing is faster. Bridenstine[1] found biopsies done with radiofrequency incision have thermal damage zones of 75 μm, which is comparable to those done with a CO_2 laser. Other studies have confirmed minimal tissue damage and biopsy margins comparable with scalpel excision.[20-22]

The high-frequency radio waves are modified by filtering and rectification to produce 4 distinct waveforms:

1. Cut—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.
2. Cut/Coagulation—this waveform consists of 50% cutting and 50% coagulation. It is designed for equal amounts of cutting and coagulation while maintaining minimal amounts of lateral heat and tissue damage and is especially useful in vascular areas.
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 a 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 utilize the optimum characteristics of radio wave 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 following formula:

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

(LH=lateral heat, T=time, I=power intensity, W=waveform, S=surface area, and F=frequency).

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

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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 healing. 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 tissue destruction as well. The fully filtered current produces the least heat, while the fulguration waveform generates the greatest amount of heat.

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

ADVANTAGES OF RADIO WAVE 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 anatomical variation or working in cavities
- Produces scarring equal to or less than scalpel or laser incisions
- No need for scalpel blades, with resulting cost savings
- No accidental scalpel injuries
- No dealing with dull scalpel blades
- Minimal safety precautions needed compared with lasers

THE PASSIVE ELECTRODE

The passive electrode is also called an antenna, passive antenna, neutral antenna plate, or indifferent electrode. This plate acts like a radio antenna by attracting the radio waves emitted from the machine, and it channels the energy back into the unit. The passive electrode is coated with a nonstick material to eliminate the possibility of burns or shocks. 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 surgical table cushion at the patient's shoulder. The closer the passive electrode is to the surgical site, the less power required, decreasing the possibility 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; placing the plate under the shoulder is adequate. The passive electrode is not necessary when using the bipolar mode.

THE ACTIVE ELECTRODE

The active electrode is the energized tip of the radio wave 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 radio wave surgery and electrosurgery. The active electrode tip can be bent to better navigate anatomical surfaces and angles. Many different types and configurations of electrode tips are available. Straight electrode tips are the most frequently used tips for tissue incision. Tungsten microneedles 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 for better closure of elliptical incisions. One electrode, the Ellman Vari-Tip, 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 this tip requires reduced power settings and produces little collateral tissue heating. The author prefers this tip for the fine skin incision of rhytidectomy. Although the pointed microelectrodes are well suited for fine incision, they are conical in cross section; the deeper they pass through the skin, the wider the incision. In contrast, a fine wire has the same diameter throughout its length.

Ball electrodes and flat cylindrical electrodes are used for coagulation of bleeding tissue and vessels, as well as the 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 telangiectases.

ADVANTAGES OF RADIO WAVE SURGERY

Radio wave surgery has many advantages compared with scalpel incision, electrocautery, and laser soft tissue incision and coagulation (Table). Simultaneous cutting and coagulation without significant lateral tissue damage is its most important advantage. The reduced heat promotes less postsurgical pain and faster healing.[1-7] Another advantage is a pressureless incision. Since the radio wave electrode channels the current to the tissue and does not cut by heat, it is merely glided through the tissue. With 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, causing dragging or bunching of the tissue.

Biopsy artifact damage is also reduced with radio wave surgery. Turner et al[6] have shown that, compared with CO_2 and Nd:YAG lasers, radio wave surgery causes significantly less tissue damage, which can affect the diagnostic ability of the pathologist. Turner et al also reported that the pure cutting waveform of radio wave surgery approaches the quality of cold knife excision.[6]

A bacteria-free incision is also possible with the radio wave electrode. Although the electrode does not heat, the resistance of the soft tissue causes a release of energy and produces steam within the cells, causing vaporization and sterilization. In addition, the electrode may be "steam cleaned" by holding the tip between layers of moistened gauze and activating the current, causing the unit to vaporize the fluid on the gauze and, thus, self-clean. Surgical debris may be easily removed from the electrode in this manner, unlike the electrocautery tip, which is cleaned with abrasives.

Clinical Applications in Cosmetic Facial Surgery

This 4.0 MHz radio wave surgery is considered a technological advance over traditional electrosurgery. Radio wave surgery can be applied to virtually any situation involving incision in which a practitioner would traditionally use a scalpel, scissors, and, in many cases, lasers.

Radio Wave Blepharoplasty

One of the most useful applications of radio wave surgery is cosmetic blepharoplasty. This modality produces scars consistent with scalpel incisions but produces significantly more hemostasis. In addition, its 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 it is not accessible to many practitioners. In addition, radio wave surgery units are portable and do not require the same safety precautions as those needed for lasers. Welch[7] has shown histologically that 4.0 MHz radio wave surgery causes less thermal damage on resected periorbital fat pads than that caused by CO_2 laser surgery.[7]

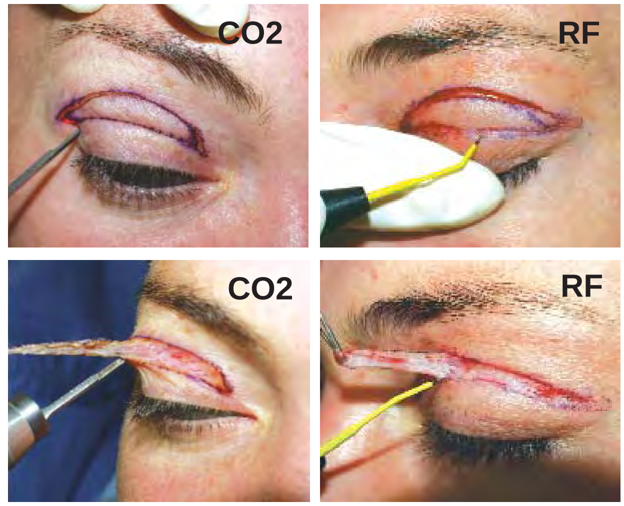

Figure 2. Both the CO_2 laser and the radio wave microsurgical tip offer excellent hemostasis.

The surgical technique for blepharoplasty involves the usual markings and local anesthetic injections. The skin incision is performed with a tungsten microneedle with a pure cutting waveform (90% cutting, 10% coagulation). Skin and muscle bleeders are controlled by grasping the area with a small forceps and touching the radio wave tip to the forceps. 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 the forceps; their base is then cauterized with a small ball electrode or a flat cylindrical electrode (the author prefers the Ellman No. 133). No clamping is necessary, as the cutting and coagulation with the radio wave electrode are excellent. The author has performed over 100 radio wave blepharoplasties with excellent hemostasis. Figure 2 illustrates the excellent hemostasis offered by both the CO_2 laser and the radio wave microsurgical tip. Figure 3 depicts the equally bloodless surgical field when removing muscle and fat from the upper eyelids, and Figure 4 shows an 18-month postoperative scar when the patient's right lid was incised with a CO_2 laser, and the patient's left lid was incised with a radio wave microneedle.

The author has performed side-by-side comparisons of 4.0 MHz radio wave surgery and CO_2 laser surgery for upper blepharoplasty. A tungsten microneedle was used with a pure cutting or a cut/coagulation (partially rectified) setting on the patient's left eyelid, and the CO_2 laser was used with an 8-watt, continuous wave setting on the patient's right eyelid. As shown in the images, both modalities provided a virtually bloodless surgical field. In addition, the radio wave surgery on the patient's left side showed a more esthetic scar in the early postoperative period (Figure 4). The 12-week comparison of

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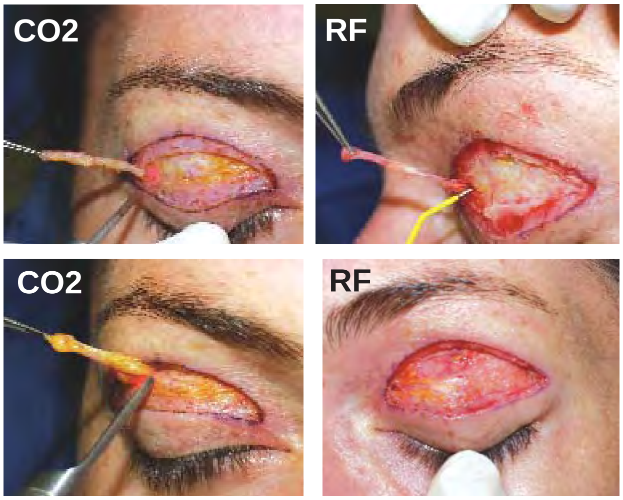

Figure 3. The CO_2 laser and the radio wave microsurgical tip both allow a bloodless surgical field while removing muscle and fat from the upper eyelids.

Figure 4. Postoperative scars after the patient's right lid was incised with the CO_2 laser, and the patient's left lid was incised with a radio wave microneedle.

the blepharoplasty scars were judged equal by the author and partners and staff members in his practice, as well as by the 10 patients.

For lower blepharoplasty, the author prefers the transconjunctival approach. The conjunctiva and capsulopalpebral fascia are incised with a tungsten microneedle, and the fat pads are identified and sectioned as previously discussed, using a small ball electrode or flat cylindrical electrode (Figure 5). The

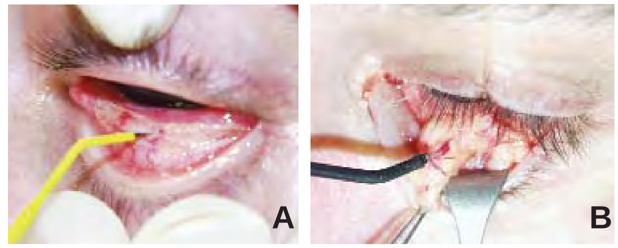

Figure 5. The conjunctiva and lower lid retractors are incised with a cut/coagulation current (A), and the fat pads are contoured with a small ball electrode (B).

conjunctiva and lower lid retractors are incised with a cut/coagulation current, and the fat pads are contoured with a small ball electrode.

Radio Wave Rhytidectomy

The author has used the microneedle or Vari-Tip electrode for preauricular and postauricular rhytidectomy incisions on a pure cutting mode and has seen the same results in healing as those with scalpel incisions (Figure 6). In addition, the subcutaneous dissection may be

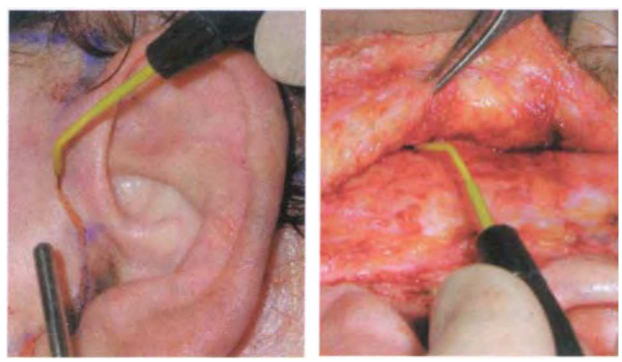

Figure 6. A microneedle is used to make the skin incision, as well as to dissect the superficial musculoaponeurotic system (SMAS) from the skin flap.

performed with the tungsten microneedle, and hemostasis of the superficial musculoaponeurotic system (SMAS) and muscle is easily performed with a large ball electrode, bipolar forceps, or simple conduction through Adson forceps (Figure 7). The ability to cut and coagulate without picking up a bipolar forceps or similar instrument makes surgery simpler and the field less cluttered. The author also uses the large ball electrode to shrink

Figure 7. Coagulation may be performed with the ball electrode or instrument conduction.

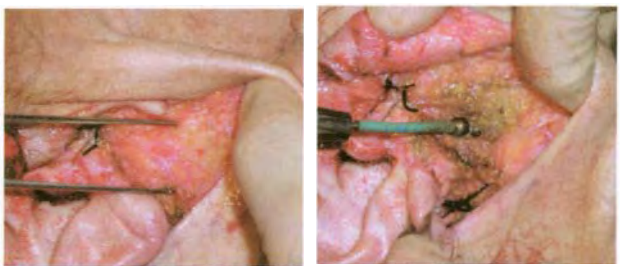

Figure 8. A preauricular protuberance of the superficial musculoaponeurotic system (SMAS) after placing placation sutures. This mound may be shrunk and flattened by gentle cauterization with the ball electrode.

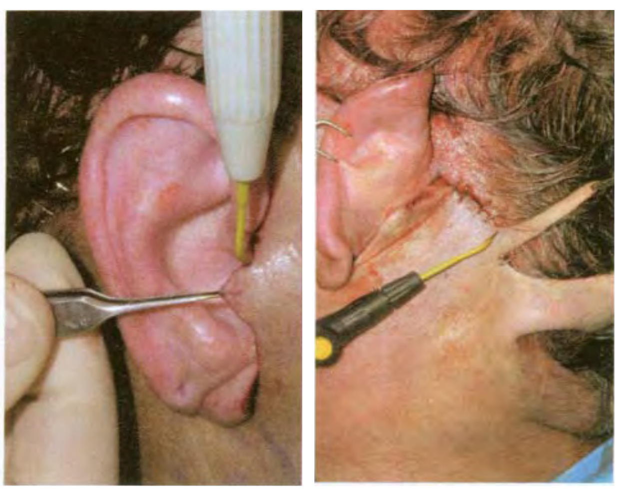

Figure 9. The microneedle is used for tissue cutback and recontouring in face-lift surgery. The microneedle provides precision on skin margins.

irregular contours from plication or lumpy areas of the SMAS. This not only recontours these irregularities but also causes shrinkage and retraction of the SMAS (Figure 8). Finally, the author feels that greater control and dexterity is available when performing cutbacks and excess skin removal during the face-lift. Even if scissors are used to trim excess skin, scalloped areas often result on the incision line. The microneedle effectively evens out these areas into a perfectly straight line (Figure 9).

Figure 10. Subject with multiple nevi and skin tags before (A) and after (B) treatment with radio wave surgery.

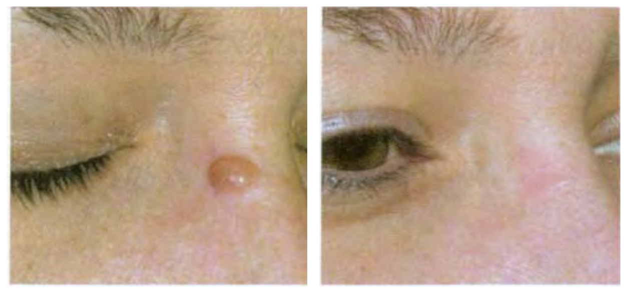

Figure 11. Low power ablation with a radio wave system produces minimal lateral tissue damage, resulting in minimal scarring.

Lesion Removal

One of the true strengths of 4.0 MHz radio wave surgery is lesion removal. Practitioners often see patients with hypopigmented depressed scars on the face from the liquid nitrogen ablation of lesions. This all too frequent scenario can be prevented by using radio wave surgery to ablate lesions. For example, a flat cylinder electrode can be used at a low power with minimal lateral tissue damage. A small ball electrode also can be used. For suspicious lesions, the loop electrode may be used as a 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 locally anesthetized, and the unit is set to the cut/coagulation setting. The author uses a surgical loupe and wipes 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, by informing the patient that a touch-up may be required to remove a remnant lesion, rather than to overtreat and end up with a depression. When treated in this manner, facial lesions leave imperceptible scars, as shown in Figures 10 and 11.

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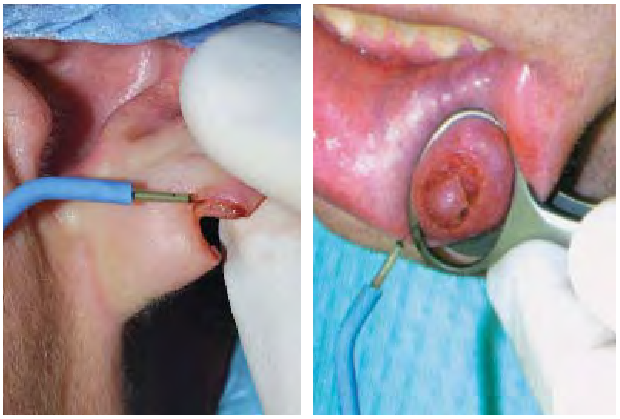

Figure 12. Fine-tipped radio wave electrodes may be used to make pressureless incisions on mobile tissues.

Mobile Tissue Incision

Incising fleshy or mobile tissue is always a challenge. One problem with the scalpel incision of fleshy or mobile tissue is that pressure is required, distorting the tissue and decreasing control and precision. The fine-tipped radio wave 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 12).

Specialty Applications

A wide variety of specialized electrodes are available for cosmetic applications, including an electrode that is specifically designed for harvesting palatal mucosa. These mucosa grafts are used for lower eyelid reconstruction and various maxillofacial applications. The electrode not only cuts an exact thickness of mucosa but also simultaneously coagulates the very vascular palatal tissues.

Insulated electrodes also are available in various sizes for hair removal and telangiectasia ablation. These insulated electrodes are designed to conduct radio waves only at the very tip, so they can be placed down a hair shaft or into an ectatic vessel without damage to the adjacent tissue. Long contoured electrodes are made for endoscopic brow and forehead lifting.

Hazards, Complications, and Caveats

Like any modality, radio wave surgery presents certain hazards and complications.[23,24] Excess lateral tissue damage is probably the most common complication and usually results from operator error (especially by novice clinicians) involving failure 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 optimum clinical response.

Radio wave surgery should not be used in the presence of flammable anesthetics, liquids, or skin preparations. Just as the smoke plume in laser surgery can be detrimental, radio wave surgery causes tissue vaporization and potential hazard from smoke 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. If central suction is used, it must be vented to the outside environment; otherwise, the smoke and smell from one area of the office are merely redistributed to another area. Special portable evacuation systems with viral and activated charcoal filters are available to ensure the safety and comfort of both operator and patient.

Radio wave surgery machines may interfere with other electromedical equipment, such as monitors. In the author's office, interference with the EKG monitor was corrected by plugging the radio wave equipment into a circuit separate from the EKG.

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. There is potential for interference with implantable cardioverter-defibrillators (ICDs). LeVasseur et al[23] have reviewed this topic and make recommendations, including possible deactivation of the ICD prior to surgery. The electromagnetic interference of radio wave surgery may cause the pacemaker to reprogram or otherwise malfunction. With 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 radio wave equipment is to be 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 available for the rare case of a cardiac emergency.

When operating on patients with pacemakers and ICDs, bipolar use of radio wave surgery is safer because the current is concentrated between the tips rather than through the patient. Short bursts of radio wave energy (less than 5 seconds) are preferable to long electrode activation periods. Pauses between the bursts allow resumption of cardiac rhythm.[24]

Conclusion

The new technology of 4.0 MHz radio wave surgery 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 apply to the very vascular and, sometimes, mobile tissues in cosmetic facial surgery.

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