Radiosurgery in periodontics: Have we forgotten it?

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Abstract:
Radiosurgery (RS) has evolved from electrosurgery and uses ultra-high-frequency radio waves at a frequency ranging from 3 to 4 MHz. It is used to address numerous soft-tissue concerns in dentistry and as well as medicine with excellent and predictable results. A review of the indexed literature disclosed that RS has been employed for various periodontal procedures such as gingivectomy, gingivoplasty, crown lengthening, minimally invasive closed osteotomy, frenectomies, operculectomies, depigmentation, gingival curettage, periodontal flap procedures, mucogingival surgeries, harvesting soft-tissue grafts, and also in implantology. Reduced lateral heat production with minimal tissue damage, faster healing, availability of specialized electrodes, increased perception, and cost-effectiveness are some of the notable advantages of RS. The evidence available implies that RS when used appropriately might be a better and economical alternative to a scalpel, electrosurgery, and laser. Inadequate knowledge on the use of this treatment modality due to short of research conducted in this area could be the reason behind it becoming obsolete. This review is an attempt to reminiscence the uses of this versatile tool in periodontal therapy and reinstate its use in present-day clinical practice.

Key words: Electrosurgery, periodontics, radio waves, radiofrequency, radiosurgery

INTRODUCTION

The harnessing of electrical energy for effective tissue management in medicine has come a long way from the use of spark gap generators, electrosurgery (ES), and electrocautery to the more recent advancements like a laser. The major objective behind the use of electrically powered modalities in surgeries is to attain simultaneous coagulation of tissues while precisely incising or excising them, ensuring with minimal tissue damage.

Radiosurgery (RS), an advanced form of ES, is defined as the use of high-frequency radio waves of 3.8MHz to incise, sculpt, ablate, or coagulate tissue.[1] The high-frequency radio waves produce a pressure less, microsmooth incision with hemostasis and minimum tissue alteration. It has become a part of the surgeon’s armamentarium with numerous applications in dentistry and medicine. Somewhere among the use of ES to the application of more advanced technologies like laser, the use of RS has become obsolete.

TIMELINE OF RADIOSURGERY

William Bovie in 1926[2] created the first monopolar electrosurgical device and paved the way for the usage of these devices in surgeries. Irving Ellman[3] began to use ES devices in dentistry. However, Flocken[4] has found that the use of these electrosurgical units burned the gingival tissues and warned against its use. Ellman[5] worked on this issue and observed that 4 MHz was the optimum frequency to produce a precise incision at the lowest temperatures. Ellman (1973)[3] patented his newly developed unit that works at 3.8 MHz known as the Dento-Surg Radiosurgical device. Goldstein[1] created the word “Radiosurgery” to differentiate the use of the patented 3.8 MHz ultra-high-frequency radio waves from ES (0.5–2.9 MHz). Garito and Flocken (1975)[4] have introduced the Dento-Surg unit in oral surgery. Pollack (1981)[5] introduced RS in dermatology. The first use of RS in gynecology was reported in 1987.[6] Later, RS has entered other surgical disciplines including ophthalmology; ear, nose, and throat; facial plastic surgery; neurosurgery; arthrosurgery; otolaryngology; endoscopic spine surgery; and proctology.[4]
The International Electrotechnical Commission (IEC) regulations pointed that RS units with the original vacuum tube unit design showed leakage of current. Other technical issues reported were associated with the type of connection plugs, the antenna plate, and the large surgical devices. Garito[7] has redesigned the original radiofrequency unit and developed the 4-MHz dual-frequency radio wave device working at 4 and 1.7 MHz frequency with a microprocessor in place of the earlier vacuum tube to meet the IEC regulations. A portable wireless radio wave (4 MHz and 500 KHz) device is the most recent modification of the RS unit.[8]

**PRINCIPLE OF OPERATION**

The radiosurgical unit consists of a transformer, power supply, amplifier, rectifier, and a wide range of electrical circuits [Figure 1]. The unit obtains power from a standard alternating current wall outlet, which is converted to direct current and passes into a tuned coil/capacitor generating the radio wave signal. The high-frequency waveform adapter alters the shape and magnitude of the radio wave produced, creating different waveforms of RS. The amplifier present will increase the power level of the waveforms produced. These amplified waveforms pass through the final coupling circuits which are connected to the electrodes.

The unit has two electrodes, a small metallic wire electrode (active) and a large metallic antenna plate (passive). When tissue is treated with RS, the radio waves pass from the active electrode to the tissue and return the unit from the passive electrode. The passage of these high-frequency radio waves through the tissue produces heat as a result of tissue’s natural resistance to the radio signal. This eventually causes cell destruction or volatilization at the tip of the electrode. The radio wave is guided through the tissue by the active electrode, leaving a path of cell destruction creating an incision.[8]

**LATERAL HEAT**

The heat produced within the surrounding tissue by the radiosurgical waveform passing through it is known as “Lateral Heat (LH).” Although the tissues tolerate certain amounts of heat, it is essential to prevent excessive LH production as it could result in tissue necrosis. Various factors influence the LH generated during RS.[9] Understanding the working mechanism of RS and the factors controlling the LH production is of utmost importance to avoid excessive lateral tissue damage.

**Time**

Slower the guidance of the electrode across the tissue, greater is the degree of the LH produced. If the electrode moves faster, smaller degree of LH is produced.[9] Kalkwarf et al.[10] established that an incision produced at a speed of 7 mm/s is most effective in minimizing the LH produced. It is also important that the electrode should remain in contact with the tissue for only a brief period of time.

**Intensity**

The intensity of power should be adequate to produce the desired results and depends on the tissue character. For tissues that are thick and fibrotic, the power setting should be slightly raised to one half to one full increment. When there is excessive bleeding, the power setting must be reduced to one half to one full increment. Higher power intensities generate sparking and charring of tissues, and insufficient power intensity causes stickiness or dragging of the electrode on the tissue.[9]

**Frequency**

The frequency of RS will affect the amount of LH produced as well as tissue healing. Maness et al.[11] found that less tissue destruction occurred with a frequency on or near 4 MHz compared to lower frequencies closer to 1.7 MHz. Lower frequencies tend to produce a less efficient cut with more LH and, in turn, delay healing.

**Waveform**

The waveforms allow control of the amount of hemostasis, choice of cut, and quantity of LH produced. There are four waveforms available in dental RS units [Figure 2].[9]

1. Fully rectified filtered
2. Fully rectified
3. Partially rectified
4. Fulguration.

Maness et al.[11] found that a fully rectified filtered waveform produced less tissue alteration compared to fully rectified or full-wave current.

**Electrode size**

Larger electrode tips need more power intensity producing more LH than thin wire electrode.[9] Kalkwarf et al. proposed that it is advantageous to wait for 8–10 s[10] before returning to the same surgical site to allow tissue cooling and large electrodes require 15 s.[12]

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**Figure 1:** Principle of operation of a radio surgical unit; D.C: Direct current; A.C: Alternating current; L/C: Resonant circuit, where L represents inductor and C represents capacitor

**Figure 2:** Different waveforms available in radiosurgery
Proximity of the passive and active electrodes
Less power is needed when the active and passive electrodes are near to each other. Bipolar electrodes have both the active and passive electrodes next to each other. When working in a wet field with the monopolar unit, the radio waves are dispersed over the liquid and no longer concentrated, resulting in decreased efficiency of cutting or coagulation. Using bipolar electrodes, the radio waves are not dispersed in the wet field, producing a better cut/coagulation. These bipolar units are adapted to various medical surgeries, but they cannot be used in dentistry with the same ease as the monopolar electrodes due to the electrode configuration.\[16\]

THE ELECTRODES
Electrodes are the primary units of the radiosurgical device responsible for delivering the desired action of cutting or coagulation. They are similar to electrodes of ES with fewer advancements. These are made of tungsten to prevent electrode heating when working at higher frequencies and thereby preventing tissue damage. The Vari-Tip electrode has a fine wire that passes through the sleeve and can be manually extended to any length desired up to 1 cm or more, allowing the use of low power settings with minimal LH production.\[14\] Electrodes are proposed to be self-sterilizing in nature. However, the protective coverings on the electrode tip and the handpiece were not affected, and clinicians would later autoclave or disinfect them. Excessive autoclaving of the electrodes can darken or corrode the tips. This led to the introduction of disposable electrode tips that aid in ensuring infection control and also eliminate the chance of needlestick injuries that may occur when disinfecting straight-wire electrode tips.\[15\] Advanced composition alloy (ACE) electrode has been developed to minimize the LH production (<10 µm), tissue damage, and tissue sticking.\[16\] Apart from the regular electrode shapes such as straight tip, ball, diamond, loop, and triangle, special tips are available for specific applications.

ADVANTAGES
With the help of various waveforms and different electrode designs available, RS offers numerous advantages and applications.\[8\]
1. Permits any degree of hemostasis
2. Prevents seeding of bacteria into the site of incision
3. Active electrodes are flexible fine wires which are easy to bend and shape as required
4. Electrodes are self-sterilizing and do not require sharpening
5. Permits soft-tissue planing
6. Provides a clear and improved view of the operative field
7. Eliminates scar tissue formation
8. Increases operative efficiency
9. Reduces chair time for each operation
10. Improves the quality of restorations by aiding impression making
11. Reduces the fatigue and frustrations of the operator
12. Minimizes postoperative discomfort
13. Allows a pressure less cut with a “paint-brush-like” stroke.

DISADVANTAGES
There are minimal disadvantages reported with the use of RS, including smoke plume produced due to tissue vaporization during RS can be a potential hazard due to particulate inhalation and can create an unpleasant smell. RS may interfere with other electromedical devices like electrocardiogram monitors.\[9\]

RADIOSURGERY IN PERIODONTICS
RS is mainly employed for soft-tissue management in periodontal practice. A review of the literature disclosed that RS is utilized for various procedures such as gingivectomy, gingivoplasty, crown lengthening, minimally invasive closed osteotomy, frenectomies, operculectomies, depigmentation, gingival curettage, periodontal flap procedures, mucogingival surgeries, harvesting soft-tissue grafts, and also in implantology.\[8\]

Gingivectomy and gingivoplasty
Hyperplastic and hypertrophic gingival tissues are often managed by gingivectomy and gingivoplasty procedures. A fully rectified waveform and a Vari-Tip straight-wire electrode are used to excise the thickened fibrotic tissue as well as hemorrhagic tissues. The tissues are beveled using a triangular or loop-shaped electrode. When performed as a crown lengthening procedure, the tissue is undisturbed for 2–3 weeks for healing prior to prosthetic preparation.\[17\] Hypertrophied tissue due to drugs such as Dilantin, irritation from orthodontic bands and braces, or irritation from dentures were also managed using RS.\[18\]

Minimally invasive closed osteotomy
This technique is indicated for gingival margin line-up, crown lengthening, gummy smile, subgingivally fractured teeth, endodontically treated teeth that exhibit a minimal ferrule effect, subgingival caries, altered passive eruption, and gingival hyperplasia. Contraindications for this technique include minimal keratinized tissue width, osteotomy more than 3 mm, triangular teeth, a very scalloped gingival architecture, and presence of thin gingival biotype. Escalante Vasquez\[19\] presented a case report on the minimally invasive closed osteotomy for treating gummy smile using electrode No. 108 B, and the gingival tissue was detached from the bone without lifting a flap forming a “kangaroo’s pouch,” followed by closed osteotomy. Advantages include less traumatic, much faster, requiring no flap or sutures, with minimal postoperative pain, and shorter healing phase. Limitations are difficulty in visualizing the osseous crest and technique sensitive.

Frenectomy and operculectomy
Other minor surgical procedures such as frenectomy,\[16\] management of ankyloglossia,\[16\] and operculectomy were also carried out using RS.

Periodontal flap surgery
Ferris\[20\] performed a periodontal flap procedure using RS. Loop electrodes were used to contour the flap edges and the inner walls of the flap with fully rectified, fully filtered waveforms to permit flap adaptation to the alveolar crest. Soft-tissue incisions such as periosteal releasing incisions for coronal advancement flap following ridge augmentation and apically positioned flaps for augmenting keratinized gingiva width were also performed using RS. It provides a reliable, rapid, and precise contour for the repositioned or replaced gingival flap.\[21\]
Soft-tissue grafting
RS is used for periodontal plastic procedures to harvest soft-tissue grafts. A specially designed electrode, the Ellman Mucotome, is used for harvesting palatal mucosa. The electrode is used on the cut (filtered) mode and can contact bone, providing the clinician keeps it moving. The use of filtered cut waveform ensures that there is no coagulation allowing graft revascularization at the donor site.

Gingival depigmentation
Pigmented areas are touched lightly with No. 135 ball-shaped electrodes or tapping the area with the No. 134 L-shaped electrodes using fully rectified cut mode (power setting at 11) for thick, hard gingiva and partially rectified coagulation mode (power setting at 7) for gingiva soft in consistency and near the mucogingival junction. Tiny electrodes (2 mm ACE electrode) are employed in narrow interdental papillary regions. Mahesh et al. observed that depigmented areas treated with RS showed minimal recurrence compared to conventional (slicing) treatment after 90-day follow-up. Based on Oringer’s exploding cell theory, the electrically generated thermal energy influences the molecular disintegration of melanin cells that are present on the basal and suprabasal cell layer of operated gingival sites. It was proposed that the LH of RS had some influence on retarding the development and migration of melanocytes, making RS more efficient in surgical depigmentation over conventional procedures.

Implantology
RS is used in implantology for giving fine nonhemorrhaging incisions during implant placement, for re-positioning of the tissues over or around the implant, for exposure of implant into use, to prepare the preprosthetic gingival tissues, and for implant detachment and granulation tissue removal in case of peri-implantitis and implant failure. No rise in temperature, clinical or radiographic changes were reported when the electrode comes into contact with implant, making it safe to use around implants.

RADIOSURGERY IN DENTISTRY
RS is also used for the following procedures in dentistry.

- Restorative dentistry: (1) Crown lengthening, (2) exposure of subgingival caries, (3) pulpotomies, (4) coagulation of pinpoint pulp exposure, (5) tissue removal for matrix placement, and (6) accelerate bleaching procedures
- Crown and bridge: (1) Troughing for impressions, (2) recontour pontic areas and denture saddle areas, (3) exposure of fractured prosthesis for repair, and (4) Tissue removal to facilitate bonded bridge placement
- Oral surgery: (1) Impactions, (2) orthodontic exposure, (3) removal of epulis fissuratum, (4) palatal stripping of the hyperplastic palate, (5) tuberosity reduction, (6) enucleate fistulous tracts, (7) apiocectomies, (8) destruction of cyst remnants, (9) incision and drainage, (10) biopsies, (11) removal of benign and malignant lesions, (12) implant flaps and exposure, and (13) soft-tissue coagulation
- Endodontic procedures: (1) Pulpectomies, (2) endodontic surgeries, (3) coagulation of fractured teeth, (5) hemostasis and sterilization of endodontic canals, (6) hyperplastic tissue removal for rubber dam placement, and (7) access internal radicular resorption
- Miscellaneous: (1) Obstructive sleep apnea (radiofrequency ablation of soft palate) and (2) trigeminal neuralgia (percutaneous radiofrequency rhizotomy).

CONTRAINDICATIONS
RS is contraindicated in patients with unshielded pacemakers and implantable cardioverter defibrillators. It is not safe to be used in presence of inflammable agents such as ethylene, propylene diethyl ether, or ethyl chloride. It is not suitable for the treatment of apthous or any viral lesions.

PRECAUTIONS
While using RS, certain precautions must be followed to avoid complications and provide an effectual outcome. In cardiac patients, physician consultation is necessary to ensure that the pacemaker is shielded and will not be affected by RS. Deactivation of implantable cardioverter-defibrillators can avoid dysrhythmias in the patient. Bipolar electrode tips are safer as the current is not dispersed throughout the patient. RS should be used in short bursts (≤5 s) to allow the resumption of cardiac rhythm. Smoke plume produced during RS should be evacuated with the help of high-speed evacuation suction. The use of surgical masks rated for microparticulate filtration and special portable evacuation systems with viral and activated charcoal filters ensures for both operator and patient safety and comfort. The use of RS units in the presence of flammable or explosive agents must be avoided. Skin must not be prepped with alcohol. The handpiece must be deactivated each time an electrode tip has to be changed. Placing the accessories that are not in use on the patient or the surgical drapes must be avoided, as possible burn or fire may occur. Following RS, areas of minimal tissue removal such as exposing subgingival decay or for roughening crown preparations can be protected by irrigating the surgical area with saline. More extensive tissue removal requires placement of periodontal packs.

HEALING AFTER RADIOSURGERY
The healing after RS is rapid without scar formation due to the minimal collateral thermal damage of the tissue. The heat denaturation of collagen by RS was found to be 75 µm, which was comparable or superior to carbon dioxide laser. Following depigmentation, margins of the tissues at the surgical site exhibited slight redness after 1 week and epithelization completed in 10 days. The healing seen clinically after the use of RS for flap procedures was comparable to that observed with conventional instruments and lasers in terms of speed and quality of soft-tissue response.

COMPARISON OF RADIOSURGERY, SCALPEL, ELECTROSURGERY, AND LASER
Incisions of RS are histologically similar to scalpel incisions and lack thermal and mechanical artifact due to the low level of thermal heat produced. The scalpel requires pressure while incising tissues and is associated with immediate bleeding, whereas RS produces precise, sterile, and pressureless incisions with simultaneous coagulation enhancing visibility. The lower frequency radio waves of ES produce more LH compared to
the ultra-high-frequency RS. The electrodes used in ES tend to become hot during the procedure, unlike the electrodes of RS in which the resistance is developed within the tissues and cutting tip does not become heated. The laser can perform many of the procedures accomplished by RS, but it is expensive and requires high maintenance compared to RS. Laser treatments are also associated with the potential for ocular damage. Furthermore, the laser incision is rather slow compared to RS.

**CONCLUSION**

RS has the potential to be employed for several periodontal treatments owing to its versatility, safety, and effectiveness, which is equivalent to the more expensive laser usage. The reason behind why it has become obsolete in a present-day periodontal practice is still unclear as there is inadequate well-controlled research carried out in this perspective. This could be due to the lack of adequate studies employing RS, lack of awareness about its versatility and benefits, or it could have been overshadowed with the emergence of the laser. The evidence available implies that when used appropriately, RS might be a better and economical alternative to other treatment modalities. More studies are required to assess the proficiency of RS and reinstate its use into the field of periodontics to avail its benefits.

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**Conflicts of interest**

There are no conflicts of interest.

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