Radiotherapy in Dentistry – A Brief Review

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Abstract

High frequency radiotherapy is one of the most important and versatile tools in dentistry in present age. It can be used in various oral surgical procedures, and is also useful in establishing hemostasis. Its main advantage over other modalities centers around a pressureless incision with minimal bleeding. Although off late there has been an increase in interest of dentists in radiotherapy leading to new radiography applications and equipment features, still the progress has been slow paced. Inadequate knowledge, and/or presence of conflicting, and at times confusing, information on the post-operative wound healing could be one of the reasons for this slow progress. This article reviews the radiotherapy principles and the use of various radiotherapy applications in dentistry.

Keywords:
Radiotherapy, dentistry, fully rectified filtered, fully rectified, partially rectified, fulguration, unipolar, bipolar


**Introduction**

The use of electricity in dentistry and medicine has come a long way from spark gap generators (1), electrocautery (2) and electrosurgery (3). High-frequency radio surgery is one of the most important and versatile instruments in dentistry today, with numerous uses ranging from performing precise surgical incision to establishing hemostasis. Radiosurgery evolved from electrosurgery, and prior to that electrocoagulation. It has a learning curve that takes time and practice to master. The common use of radiosurgery is due in part to the advancement of the technology as well as the increased research in the field over the years (4).

In 1972, Dr. Arthur Goldstein created the International Academy of Radiosurgery and defined the word radiosurgery as “the use of high-frequency radio waves of 3.8 MHz to incise, sculpt, ablate, or coagulate tissue” (5). Radiosurgery is the passage of high-frequency radio waves through tissue for the purpose of dissection. By using the appropriate waveform and wave frequency, the surgeon can create skin incisions and deep tissue dissection with little destruction of the surrounding structures. Excellent hemostasis during dissection is achieved by using the correct waveform and proper electrode. Minimal tissue destruction and good hemostasis result in minimal swelling and bruising with excellent wound healing (6). It offers the advantages of fast and efficient incisions/excisions with an excellent field of visibility (7). The clear field of vision provided accelerates surgery time and therefore decreases the time of the patient under general anesthesia (8). The patient receives a pressureless cut with a minimal amount of bleeding that often requires no suturing. It is safe for the surgeon, staff, and patient. It is cost effective.

Radiosurgery describes the most advanced form of electrosurgery. It is the removal of soft tissue with the aid of radio frequency (RF) energy. This electromagnetic energy operates between the frequencies of 3.0 megahertz (MHz) to 4.0 MHz, with 4.0 MHz being the optimal frequency. The older electrosurgical instruments, when performing similar procedures, operated at lower frequencies of 1.0 MHz to 2.9 MHz produce more lateral heat to the surrounding tissues and should be avoided when in close proximity to bone (9,10).

**Historical Background**

Electrosurgery has been used in dentistry for more than 75 years in dentistry since it was first used in 1847 to destroy a neoplasm by Cusen, a Russian scientist (11). The original electrosurgical equipment developed by Coles, Martin, and Ellman has been downsized with the development of more sophisticated waveforms and cutting tips. Dr. Irving Ellman developed the Surgitron that produced high frequency electrical current with minimal lateral heat and damage. In 1973, Dr. Ellman was granted a patent on 3.8-megahertz and 4 therapeutic waveforms. The unit was developed with

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In 1995, Ellman International used microchips in designing the Surgitron Dual Frequency and was able to produce a consistent output of 4 megahertz. This higher frequency resulted in even less lateral heat (6). The Ellman Surgitron first became popular in the field of dentistry (12-14), and its value was later appreciated for the removal of skin lesions (15-20). Radiosurgery is now used in gynecology, otolaryngology, general practice and veterinary medicine (21-27). Neurosurgeons find radiosurgery useful in the treatment of discogenic low back pain and dermatologists use it for the obliteration of facial telangiectasias (28,29). Ophthalmologists are finding radiosurgery to be useful in oculoplastic procedures and in retinal procedures to drain subretinal fluid (30-36).

Indications In Dentistry

Radiosurgery uses a 4 MHz radiosignal to produce a fine microsmooth incision with no overt lateral heat being sent to the surrounding tissues. This is extremely important for extensive areas of oral surgery, where proximity to the underlying soft and hard tissues requires a delicate incision. Traditional electrosurgical machines with lower frequencies and lasers produce higher temperatures in tissues and are not recommended for this and other oral surgical procedures (7).

In dentistry, radiosurgery can be used for simple gingivectomy and gingivoplasty, oral biopsy, epulis removal, tonsillectomies, frenectomy, periodontal surgery, oral tumors and cyst removal, lingual surgery and biopsy, palatal surgery and biopsy, establishing hemostasis in the oral cavity, tissue planing, operculectomy i.e. removal of overgrowth of fibrous tissue over the occlusal surface of an embedded tooth, excision of granulomatous tissue, oral abscess incision and drainage, subgingival decay exposure and the placement of a class V-restoration (8). It can also be used for implant exposure (37).

In prosthodontics it can be used for crown lengthening and "trough" procedures for crown impressions. Troughing by definition is the preparation of gingival tissue by cell vaporization prior to taking impressions of teeth that have been prepared to receive a dental prosthesis. It can also be used for “minimally invasive closed osteotomy” which is a new minimally invasive crown-lengthening procedure that is predictable and easy to use (38). In the non-surgical management of interdental papilla loss following extraction of...
anteri or teeth, where some time has passed since the extraction, the soft tissue can be sculpted with radiosurgery before an ovate pontic is placed. This ovate pontic supports the proximal papillae, the facial soft tissue and the healing gingival tissue (39).

Radiosurgery can also be used for esthetic periodontal surgery involving the removal of gingival pigmentation due to excessive amounts of melanin (7).

Contraindications And Precautions

In order to achieve success with the use of radiosurgery, it is important to be aware of the contraindications and precautions (40).

1. Pacemakers- If a patient has pacemaker, the radio signal could technically interfere with its operation. The older pacemakers were not shielded, which put the patient at high risk from external radio signals. However, nowadays with advanced technology, the newer pacemakers are shielded, thus deflecting any outside radio signals. It is advisable to check with the patient’s cardiologist and to keep a note of his or her records.

2. Implantable Cardioverter Defibrillator- An ICD system monitors and treats cardiac arrhythmias via a pulse generator that is implanted in the patient’s chest. The device continuously monitors the heart’s function and delivers electrical energy to the heart when it senses arrhythmias. It is advised to refrain from radiosurgery when treating patients with an ICD or check with the manufacturer of the particular system first.

3. Ethyl chloride- It is contraindicated due to its inflammable nature.

4. Nitrous oxide and oxygen- Radiosurgery can be performed safely using nitrous oxide and oxygen. However, when working with an inflammable gas, such as ethylene, propylene or diethyl ether, one should be aware of the explosive properties of the particular gas as it is possible to produce a spark by touching a metal restoration or through the use of excessive power.

5. Odor- This can be controlled with the use of high-speed evacuation suction. A plastic evacuation tip used in close proximity to the surgical site will help eliminate the odor.

Principles of Radiosurgery

Radiosurgery delivers low-temperature, high-frequency (4 MHz) radio wave energy to the tissues through the metal tip. The radio waves pass from a hand-held active electrode to a passive electrode positioned very near or beneath the patient. Tissue resistance to the radio wave transmission causes an ionic agitation in the cells at the tip of the active electrode, resulting in molecular friction (41), volatilization of the cells at the tip of the electrode and subsequent heating of the tissue. This narrow path of cell destruction creates a smooth incision with minimal lateral cell damage.

Several factors affect precision of tissue dissection (41) and the amount of lateral heat generated. By varying these parameters, the amount of cutting and coagulation can be varied. By increasing the diameter of the electrode, the intensity of the power and the time the electrode is in contact with the tissues causes more lateral heat. Both the waveform and the frequency of the current affect the amount of lateral heat generated. The fully rectified filtered waveform, which is a continuous wave, causes the least amount of lateral heat. By interrupting the continuous
flow to varying degrees, the amount of lateral heat is increased. The amount of lateral heat generated is inversely proportional to the frequency of the signal. The advantage of this very high frequency is that cutting and hemostasis can be produced with much less lateral heat and tissue destruction than with other electrical instruments that use a much lower frequency. Type of electrode also affects the precision of tissue dissection and lateral thermal damage (41).

The main advantage of radiosurgery can be found in its ability to produce coagulation in an operative area which would often have extensive bleeding. With any device that creates thermal energy to cut or ablate tissue, heat may be dissipated by diffusion into adjacent tissues (conduction), or into the circulating blood. The resulting lateral thermal injury to tissues may result in delayed healing and increased risk of wound dehiscence (41).

Studies by Hulcrantzband Ericsson and Miller report less thermal damage and faster healing with the 4 MHz Radiowave technology over the scalpel and lasers. Using hamster tongues and a machine that controlled speed and depth of cut, Maness and his colleagues showed that less lateral tissue destruction occurred with 4.0 than with 2.8 or 1.7 megahertz. They also demonstrated that the continuous waveform produced less injury than the fully rectified waveform (42).

Wave Form Types and Properties

There are four radiosurgery waveforms available in the dentistry. These waveforms are fully rectified filtered, fully rectified, partially rectified and fulguration. The variety of waveform allows control of the amount of hemostasis and choice of the type of cut. It is important to be aware of which waveforms each machine is equipped with in order to establish the procedures that can be safely performed (40).

**Fully Rectified Filtered Waveform**

The fully rectified filtered waveform is a pure continuous form of high-frequency energy. The filtration results in a continuous non-pulsating flow of current which provides micro-smooth cutting. With produces the least amount of lateral heat and tissue shrinkage. The fully filtered waveform resembles the scalpel incision the most and is recommended in any application where trauma must be minimized as much as possible. It is the only waveform that allows cutting in close proximity to the bone, due to the minimal amount of lateral heat produced (40). The fully rectified waveform is a full wave current that produces cutting with some coagulation and is good for tissue dissection other than skin. If it is used for skin incisions, there is a higher risk of scar formation. By using additional electronic components to filter out the constrictions as each wave begins and ends at zero, the fully rectified current can be converted to a continuous current without an appreciable coagulation effect (43).

The applications for the filtered waveform include the following:

- Biopsy procedure – due to the nature of the waveform no coagulum is produced, thus providing a clean cut of specimen for the pathologist’s diagnosis.
- Troughing procedure.
- Frenectomies.
• Incision and drainage.
• Grafting procedures.
• Mucogingival or osseous surgery.
• Implant flaps.

An oscilloscope is used to measure the waveform being produced by a radiosignal. A fully rectified filtered waveform is demonstrated on an oscilloscope as a smooth unmodulated or uninterrupted radio wave.\textsuperscript{40}

**Fully Rectified Waveform**

The fully rectified waveform is a full wave current that has been modified by electronic filtration; it produces cutting with simultaneous hemostasis. When an incision is made, cauterization occurs on either side of the electrode tip. The fully rectified waveform does create tissue shrinkage and additional lateral heat and therefore should not be used in close proximity to the bone (40).

The applications for the filtered waveform include the following:
• Gingivectomy/ gingivoplasty type procedures.
• Palatal stripping of a hyperplastic palate.
• Epulis removal and ridge re-contour.
• Pulpotomies.
• Pericoronal flap removal.
• Removal of tissue exposing gum line decay.
• Removal of tissue around anterior composite for visibility and elimination of the ‘pink composite.’
• Removing interproximal tissue for ease of matrix placement and elimination of overhanging margins.
• Removing tissue around fractured facings or crowns for ease of facing reconstruction.
• Removing tissue to facilitate bonded bridge placement.
• Trough procedures for crown impression on the posterior teeth.

The fully rectified waveform has the advantage of cutting with hemostasis. The fully rectified waveform is demonstrated as a full wave-modulated signal when viewed on oscilloscope (40).

**Partially Rectified Waveform**

The partially rectified waveform is an intermittent flow of the high-frequency current which is excellent in producing hemostasis of the soft tissue. The partially rectified waveform produces a great amount of lateral heat and tissue shrinkage; therefore it is not used for coagulation in close proximity to the bone or when performing osseous surgery.

When coagulating soft tissue, the area should first be freed of blood using a gauze or air from a syringe. The electrode, which is usually a ball or bar in shape, is placed on the bleeding site or bleeding vessel (40).

The applications for the partially rectified waveform include the following:
• Coagulation of soft tissues.
• Desensitizing dentin and cementum from cervical erosion.
• Bleaching endodontically treated teeth.
• Drying out and sterilization of endodontic canals.

The oscilloscope depicts a ‘half-wave’ modulated waveform of the partially rectified waveform. The partially rectified waveform
provides excellent coagulation of the soft tissue (40).

**Fulguration Waveform**

The fulguration waveform is a half-wave current that has a dehydrating effect on the tissues. The fulguration waveform produces the greatest amount of lateral heat. The fulguration waveform is for coagulation and destruction of cyst remnants only and can be used near bone because the electrode does not touch the tissue. The electrode, usually pencil- or spear-shaped, is positioned about 0.5mm above the surface of the tissue. When activated, a spark is produced by the initial surge of current; this spark jumps from the electrode to the tissue causing coagulation to the point of carbonization (40).

The applications for fulguration or spark-gap include the following:

- Hemostasis involving osseous surgery.
- Removal and destruction of any cyst remnants from a biopsy or apicoectomy.
- Destruction or enucleation of fistulous tracts.
- Coagulation of a pinpoint pulpal exposure.

Fulguration provides excellent coagulation and dessication for the many clinical applications in dentistry. The oscilloscope depicts the erratic flow of current due to the highly damped waveform of the radio signal (40).

The differences amongst the four waveforms available in dental radiosurgery are shown in table 1.

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**Monopolar And Bipolar Radiosurgery**

Radiosurgery offers the ability to perform as both a monopolar and a bipolar instrument (40). Conventional electrosurgery devices are monopolar, whereby tissue is cut by means of an advancing spark with the patient grounded and in the electrical loop (37). In the monopolar mode, the incision is made with a fine tungsten wire. This mode is used to delicately remove or recontour tissue. This modality has certain clinical disadvantages, including sparking, spread of the electrical current, and potential thermal damage to the tissues because of heat generation, which have limited its application.

Bipolar radiosurgery is the latest advancement in the field. This form of surgery can now be accomplished with the use of a high-frequency radiofrequency (RF) unit. Bipolar surgery is used for excision as well as hemostasis of soft tissue. The bipolar electrode consists of two parallel wires, one to make the incision and the other to act as the antenna to receive the RF energy. This modality is believed to minimize transmission of the RF to the surrounding tissue and thereby minimizing any lateral heat. This modality has been recommended when exposing an implant as well as coagulating in the presence of an implant because the signal is absorbed by the adjacent electrode tip. This absorption minimizes any heat transfer to the implant should the electrode inadvertently touch the implant (37).

The latest development is to couple the bipolar electrodes with the more desirable radiosurgical wave. This waveform operates at a higher radio frequency of 4.0 MHz than the bipolar electrosurgical signal of 2.0 MHz.
Research has shown that high-frequency radiosurgery produces less tissue alteration and lateral heat to the surrounding tissue than the low-frequency electrosurgical signal (9).

Ellman International has taken bipolar surgery one step further by developing an instrument that is both monopolar and bipolar. The clinician who is familiar and comfortable with monopolar radiosurgery can continue to use this modality for all general dental procedures. When treatment is in close proximity to implants or large metal restorations, the bipolar modality can be readily used (9).

Features of bipolar and monopolar electrosurgery devices are given in table 2.

Comparison of Scalpel, Laser And Radiosurgery/Electrosurgery

Incisions produced by radiosurgery are similar histologically to those produced by a scalpel. These incisions lack thermal and mechanical artifact due to the low level of thermal heat produced. The scalpel requires pressure on incision with immediate bleeding and compromised surgical visibility. Electrosurgery produces more tissue alteration and histologic thermal artifact as a result of the increased lateral heat produced by the low frequency radio wave of 0.5-2.9 MHz. the laser has been shown to histologically produce sharp and thermal artifacts due to the increased lateral heat and thereby increases tissue alteration (40).

A comparison of the scalpel, the laser and radiosurgery/electrosurgery is as follows:

Scalpel
- The blade is rigid – the shape cannot be altered.
- It requires cutting pressure.
- It seeds bacteria into the incision site.
- It can be autoclaved – autoclavable blade and handpiece.
- It produces scar tissue.
- It requires a finger fulcrum near the incision site, obscuring vision.
- Hemorrhage obscures vision.

Laser
- There is a flexible fiber delivery system.
- It makes a pressureless cut.
- It is self-sterilizing and produces a sterilized incision.
- The handpiece cannot be autoclaved.
- It produces little or no scar tissue.
- It eliminates bleeding or hemorrhage; there is better visibility.
- It is larger in size – maintenance and availability of repair are a factor.
- It is not cost effective.

Radiosurgery/Electrosurgery
- An electrode cutting tip can be bent or altered to the desired shape.
- It makes a pressureless cut.
- It is self-sterilizing and produces a sterilized cut.
- Some handpieces and electrodes can be autoclaved.
- It produces little or no scar tissue.
- It requires hand support and finger rest.
- It eliminates bleeding or hemorrhage; there is better visibility.
- It is small in size; maintenance and repair are readily available.

Comparison between scalpel, laser and radiosurgery/electrosurgery is given in table 3.
<table>
<thead>
<tr>
<th>Waveform</th>
<th>Usage</th>
<th>Tissue sectioning</th>
<th>Coagulation</th>
<th>Lateral heat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fully Rectified Filtered</td>
<td>Pure cutting, Skin incisions</td>
<td>Excellent</td>
<td>Minimal</td>
<td>least</td>
</tr>
<tr>
<td>Fully rectified</td>
<td>Cutting with hemostasis, Subcutaneous dissection</td>
<td>Very good</td>
<td>Very good</td>
<td>more</td>
</tr>
<tr>
<td>Partially Rectified</td>
<td>Coagulation on soft tissue, Deep dissection and hemostasis</td>
<td>Very poor</td>
<td>Excellent</td>
<td>Slightly greater</td>
</tr>
<tr>
<td>Pulsation</td>
<td>Superficial destruction and coagulation near bone</td>
<td>None</td>
<td>Excellent for osseous surgery</td>
<td>Greatest</td>
</tr>
</tbody>
</table>

**Table 1**: Differences among the four waveforms

<table>
<thead>
<tr>
<th></th>
<th><strong>BIPOLAR</strong></th>
<th><strong>UNIPOLAR</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Ease of use</td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>No heat dispersal</td>
<td>-</td>
</tr>
<tr>
<td>3.</td>
<td>Clean surgical site</td>
<td>-</td>
</tr>
<tr>
<td>4.</td>
<td>Hemorrhage control</td>
<td>-</td>
</tr>
<tr>
<td>5.</td>
<td>Can be used in a wet field</td>
<td>-</td>
</tr>
<tr>
<td>6.</td>
<td>Atraumatic</td>
<td>-</td>
</tr>
<tr>
<td>7.</td>
<td>Cutting/coagulation controlled With a foot pedal</td>
<td>-</td>
</tr>
<tr>
<td>8.</td>
<td>No sparking of touched pedal</td>
<td>-</td>
</tr>
<tr>
<td>9.</td>
<td>Coagulation necrosis</td>
<td>-</td>
</tr>
<tr>
<td>10.</td>
<td>Rapid post-op healing</td>
<td>-</td>
</tr>
<tr>
<td>11.</td>
<td>Minimal post-op discomfort</td>
<td>-</td>
</tr>
<tr>
<td>12.</td>
<td>Time required between cutting strokes</td>
<td>-</td>
</tr>
<tr>
<td>13.</td>
<td>No separate ground needed</td>
<td>-</td>
</tr>
</tbody>
</table>

**Table 2**: Features of Bipolar and Monopolar electrosurgery devices
A smoke evacuation device should always be used to catch the plume that is generated while dissecting or coagulating with the unipolar or bipolar hand pieces. Reports have indicated that the smoke byproduct from thermal destruction of tissue by an electrosurgical unit can contain toxic gases such as hydrogen cyanide, benzene, and formaldehyde. The plume can also contain live cellular material such as blood fragments and viruses. The National Institute for Occupational Safety and Health published a report stating that “Generally speaking, the use of smoke evacuators is more effective than room suction systems to control the generated smoke from non–endoscopic laser/electric surgical procedures” (44,45).

A very light touch should be used because the electrode can cut through tissue very easily and quickly. It is recommended that the operating surgeon try several power settings for each combination of electrode and waveform. The goal is to use enough power to have the electrode slide easily through the tissues but not to have any sparking.

### Healing after Radiosurgery

Histological research has been used to evaluate many of the differences in the incisions produced by scalpels, lasers and electrosurgical/radiosurgical procedures. Epithelial and connective tissue healing following electrosurgical incisions has been researched by Kalkwarf, Krejci and Wentz. The research has shown that excisions with both filtered and rectified currents produce

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**Table 3: Comparison between scalpel, laser and radiosurgery/electrosurgery**

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Scalpel</th>
<th>Laser</th>
<th>Radiosurgery/electrosurgery</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variety of incisions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Excisions</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Cutting tip</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Ability to obtain biopsies</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Self-sterilizing</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Production of a sterilized incision</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Elimination of bleeding</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
<tr>
<td>Healing time</td>
<td>Some</td>
<td>Some</td>
<td>Some</td>
</tr>
<tr>
<td>production of scar tissue</td>
<td>little</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>Ability to plane soft tissue</td>
<td>Yes</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
initial wound healing characteristics that are similar to those reported for scalpels. The electrosurgical incisions had little or no hemorrhage or clot formation and yet they exhibited similar healing characteristics to scalpel incisions. The healing times for electrosurgical and scalpel incisions were found to be the same (40).

A study by Kurihara et al has shown that High-frequency radiosurgery can meticulously cut soft tissue by vaporizing the moisture in the cells, however, irreversible changes may occur because of the heat degeneration. The high-frequency radio surgery can be effectively used for periodontal treatment as long as the characteristics of the device are well understood and invasion of the tissue is limited (46).

**Conclusion**

Radiosurgery has several applications in almost all branches of dentistry, but this technique is still not very widely used. Previously, electrosurgery has always had some limitations in the oral cavity. Some problems included its inability to touch bone or metal, high heat and current spread, the need for a grounding pad, and the fact that it cuts by an advancing spark. These limitations have limited its acceptance by many general dentists and almost a complete avoidance by periodontists and oral surgeons. But with the advent of new technologies like radiosurgery, the scenario is changing fast as the clinicians are assured about its relatively less complications and ease of handling as compared to its predecessor technologies. Regular users of radiosurgery know from experience, that when radiosurgery is applied according to principles, predictable and good wound healing can be achieved. Though radiosurgery requires more knowledge and skill, and has a definite learning curve, the advantages out number and outweighs its disadvantages. If the clinician practices radiosurgery techniques applies them clinically according to the principles, clinician will surely find radiosurgery to be of immense use in clinical dentistry.

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