

**Advances in  
Surgical Techniques**

**Thermo-Optically  
Powered  
(TOP™) Surgery**

By  
Felix Feldchtein, Ph.D.  
Gregory B. Altshuler, Ph.D., D.Sc.

## About the Authors

*Felix Feldchtein: Ph.D., has over 20 years of experience in light-based medical technologies. He pioneered the Optical Coherence Tomography technology for noninvasive imaging. He contributed to over 100 scientific publications, 7 handbook chapters and holds over 20 patents. Dr. Feldchtein is currently VP of Research and Development at Dental Photonics, Inc.*

*Gregory Altshuler: Ph.D., D.Sc., is one of the early pioneers of laser technology in medicine, with his first dental laser developments going back almost 30 years. Many of the laser systems used today are based on technologies proposed by Dr. Altshuler. He has published over 180 scientific publications, 4 books and holds 110 patents. Gregory is a Director and Scientific Advisor for Dental Photonics, Inc.*

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Dental Photonics, Inc.

1600 Boston-Providence Highway

Walpole, Massachusetts 02081

U.S.A.

Tel: 781.754.7900

Fax: 781.752.2010

Email: [info@dentalphotonics.com](mailto:info@dentalphotonics.com)

Website: [www.dentalphotonics.com](http://www.dentalphotonics.com)

## Introduction

Dentistry has made great strides in the past few years. During this time, dental techniques have become more challenging and intricate as our understanding of clinical interactions increases. However, dental professionals today are working with surgical instruments that have difficulties meeting the clinical challenges.

This paper will look at the shortcomings of existing surgical instruments and evaluate a new technology that promises to meet or exceed the clinical challenges while providing new treatment modalities for both the dental specialist and general dental practitioner.

## Evolution of Surgical Techniques

The instruments available today to perform dental surgical techniques represent hundreds of years of evolution, starting with the scalpel in the 1800's, the Electrosurge in the 1920's and different types of lasers over the course of the last 25 years. The following are the primary instruments available today:

- **Scalpel:** Cold blade that cuts quickly and precisely, but requires chemical and/or mechanical bleeding control and sutures. No thermal impact or coagulation.
- **Electrosurge:** An electro-thermal technique which cuts soft tissue quickly, but leaves a wide zone of thermal necrosis and is often associated with post-operative pain, unpredictable tissue recession and/or overgrowth<sup>2</sup>. Cannot be used around metal crowns or implants.
- **Diode Laser:** Fine contact cutting instrument with hemostasis, but cutting is very slow; may stall and drag, especially in fibrous tissue; unpredictable zone of collateral thermal damage. Good predictability of final margins.
- **CO<sub>2</sub> Laser:** The first laser used in dentistry and historically the oral surgeon's high-tech instrument of choice for non-contact cutting, but large and expensive. Considered too cumbersome for routine adjunctive soft tissue procedures. Can be very destructive for tooth

and root structures if used improperly. Non-contact surgery requires precise three-dimensional control of the focal point for laser radiation on tissue, making it more technique sensitive and difficult to learn than contact techniques.

- **Erbium Lasers:** Efficient soft tissue cutting instrument, but large and expensive. Usually requires chemical or mechanical bleeding control. Existing Erbium lasers are pulsed lasers with low repetition rates, which results in uneven margins; may also cut or adversely affect tooth and root structures if exposed to the laser with sufficient power density; minimal hemostatic with the water spray turned off. Like the CO<sub>2</sub>, non-contact surgery requires precise three-dimensional control of the focal point for laser radiation on tissue, making it very technique sensitive and difficult to learn.

## Challenges of Surgical Techniques

No one instrument is capable of fulfilling the needs of dentists and patients for the entire range of surgical procedures and an increasingly sophisticated clientele. In fact, the optimal surgical instrument would have to comply with patient

demands for comfortable procedures with an aesthetically appealing outcome and with dental practitioner's need for efficient procedures with predictable outcome. Challenges that dental practitioner's face include the following:

### 1. Maintaining a Clean Operating Field with Consistent Visibility

Bleeding during the use of the scalpel or other instruments obstructs the field of vision and slows down or stops the procedure until appropriate measures to stop bleeding have been taken. This is a major problem for many dentists and probably one of the primary reasons for referring patients out when more extensive soft tissue procedures are necessary.

### 2. Achieving Smooth, Snagless Cutting with Tactile Feedback

While the scalpel is usually easy to guide along a planned trajectory, some instruments, especially the diode laser are known for stalling and dragging during the cutting process. The laser fiber intermittently loses its ability to cut and catches on tissue. To remedy this problem, the fiber must be re-initiated frequently in order to cut. Stalling and dragging can be frustrating and time consuming, and, if not immediately noticed, may result in unnecessary collateral thermal damage, because the time on tissue is unnecessarily extended. Some laser devices such as the CO<sub>2</sub> or Erbium lasers work in a non-contact mode and have no tactile feedback, which deprives the dentist of the ability to "feel" the tissue while cutting. This is a major obstacle to the use of these lasers for soft tissue surgery.

### 3. Providing Controlled Thermal Collateral Damage

Any surgical instrument with a thermal component, especially electrosurgery instruments, has the tendency to cause thermal damage during cutting. This is a function of the heat created and the speed at which the cutting instrument glides over tissue.

Classic electrosurgery systems are notorious for extensive collateral thermal tissue damage, and they may also damage tissue and bone around implants if touched. Diode lasers may also produce thermal tissue damage that may be more or less extensive as a function of cutting speed (see Figure 3 below). Both of these modalities are technique-sensitive, so there is insufficient control over thermal collateral damage.

### 4. Reducing Time on Tissue

For standard diode lasers with fixed power, collateral tissue damage depends heavily on the speed of cutting. With low speed caused by a snag or drag, the extent of collateral damage can exceed 1 mm. Hemostasis requires no more than 200 – 500 μm, so 1 mm or more of tissue coagulation corresponds to a significant over-treatment. Extensive thermal tissue damage has multiple implications for the success of a procedure, the postoperative phase and the aesthetic outcome. The result for patients may be similar to a third degree burn on skin; 1) extensive tissue necrosis, 2) long healing times, 3) formation of scar tissue and 4) uncontrollable tissue recession. Controlled thermal collateral damage is essential to the quality of treatment.

### 5. Protecting Sensitive Structures from Overheating

Removing soft tissue on or around structures such as teeth or implants is a point of concern when using diodes and other lasers in the 800 – 1,100 nm range. This laser radiation can penetrate deep into tissues and heat up highly absorbing implants that conduct heat to surrounding soft tissue and bone. Extensive collateral thermal damage to these structures is possible. Monopolar electrosurgery is

not recommended around metal objects such as implants.

## 6. Maintaining Hemostasis and Wound Sealing

Non-thermal cutting techniques like the scalpel require chemical and mechanical methods to stop bleeding and seal blood vessels. The resulting open wounds may also require some kind of wound closure e.g. sutures to enhance the healing process and avoid infection. The thermally oriented surgical instruments, such as the Electrosurge, diode lasers and CO<sub>2</sub> lasers, cauterize as they cut to a depth of more than 200 µm, so blood and lymphatic vessels are sealed and wounds are protected from infection. An exception is the Erbium cut, which does not provide sufficient cauterization (less than 50 µm) for many blood vessels. That said; additional methods of hemostasis are necessary.

## 7. Avoiding Technique Related Operative and Post-Operative Discomfort

Different surgical techniques and procedures have very different requirements for pain control. Electrosurgery leads the list of pain-inducing techniques due to the sometimes extensive burning of tissue. The sometimes excessive fumes and smell of burning tissue also have a psychological effect on patients and may enhance the pain perception. The postoperative phase may be long with considerable discomfort because of the excessive tissue damage.

Due to the unpredictable outcome, some procedures will require corrective action. Diode laser techniques have lower pain during the surgery and reduced discomfort after surgery, but may encounter similar problems associated with excessive tissue damage if it occurs. The scalpel has moderate pain control during the procedure but loses points in the post-operative phase due to suturing and the post-operative visit needed to remove sutures for some procedures. This is definitely not popular with patients and results in additional chair time.

## Advances in Surgical Techniques:

Any new surgical technology would have to meet the challenges of a wide variety of surgical indications and offer new treatment modalities while avoiding the pitfalls of existing conventional technologies. The concept of *TOP Surgery* was born as a surgical technology and accompanying technique with the following objectives:

- Ensure a clean operating field with consistent visibility.
- Precisely control thermal collateral damage.
- Cut soft tissue like a scalpel, i.e. smoothly and without snags, with pinpoint accuracy and tactile feedback.
- Minimize the possibility of overheating of tooth structures, implants or tissue damage.
- Cut and cauterize simultaneously for hemostatic control and wound sealing.
- Avoid technique-related operative and post-operative discomfort.

## What is TOP Surgery?

TOP Surgery is a technology that cuts, cauterizes and disinfects soft tissue for oral surgery. It uses a computer-controlled semi-conductor laser as a power source whose power is converted into thermo-optical power in the system's *Thermo-Optical Powered TOP Tip* (see Diagram 1 below). Real-time sensors continuously monitor the thermal power at

the *TOP Tip*. A regulating mechanism called Automatic Power Control (APC) continuously adjusts the output power of the laser to ensure constant preset temperature at the *TOP Tip*, thus maintaining constant cutting conditions for soft tissue almost independent of the speed of cutting.

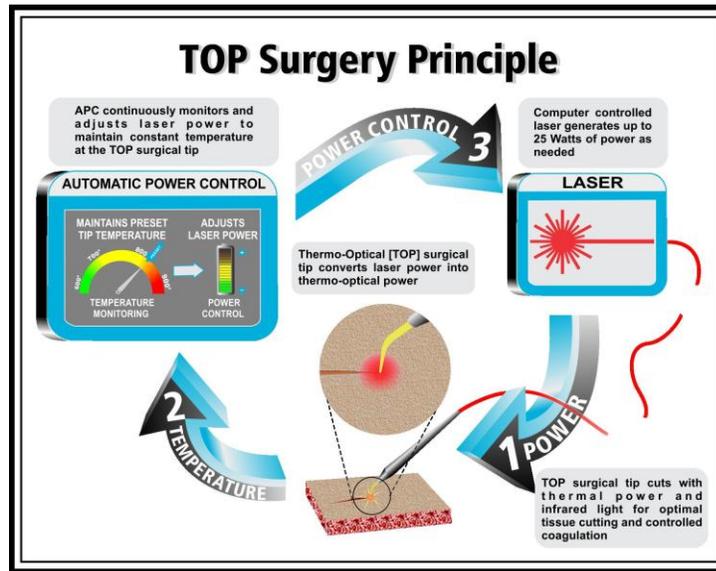
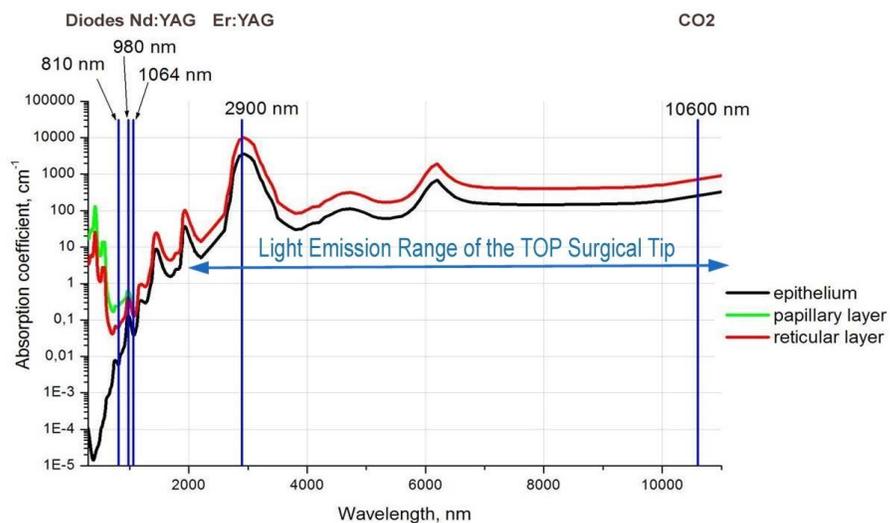


Diagram 1: TOP Surgery Principle

## Diagram 2: Absorption characteristics of soft tissue

TOP Surgery cuts and cauterizes soft tissue more effectively with its combination of heat and infrared light emission: *Thermo-Optical Power*.



Note that the scale is logarithmic, so the tissue absorption of infrared light emitted by the *TOP Tip* at 2900 nm is about **10,000** times higher than that of diode laser light at 980 nm.

## How does Thermo-Optical Power Work?

The power source of a *TOP Surgery* system is a laser. Laser light is monochromatic, that is light of one specific wavelength with low absorption in oral soft tissue<sup>4</sup>. In the *TOP Surgery* system, this light is transported to a *TOP Tip*; there, the laser light undergoes a conversion from monochromatic light to thermal power and polychromatic light with wavelengths in the range of 1,400 -11,000 nm. The vast majority of the laser light power is consistently converted to thermal power in the surgical tip of the *TOP Surgery* system.

### 1. Thermal Power

The thermal power that is created in the *TOP Tip* constitutes the primary cutting mechanism. During surgery, the *TOP Tip* is in direct contact with soft tissue, and thermal power is transported to the soft tissue surface conductively to cut. The dentist maintains tactile feedback at all times during the cutting process.

### 2. Optical Power

In the *TOP Tip*, a part of the initial laser light is converted to optical power; polychromatic infrared light that radiates from the tip with wavelengths from about 1,400 nm to 11,000 nm. These wavelengths are highly absorbable by soft tissues as shown in the Diagram 2 above. The average absorption coefficient for this polychromatic infrared radiation is about the same as for the CO<sub>2</sub> laser with a 10,600 nm wavelength, known for its excellent soft tissue cutting and coagulation capabilities. The absorption of this emitted optical radiation by soft tissue during cutting has an enhancing effect on the cutting and cauterizing power of the *TOP Surgical* system. The result: the *TOP Tip* will cut faster and cauterize tissue for hemostasis more effectively because of the optical power emitted from the *TOP Tip*.

## Elements of the TOP Surgery Technology

In research leading to the development of the *TOP Surgery* technology, the key factors contributing to thermal conductive cutting were evaluated and optimized. The objective was to provide a cutting instrument with:

- Optimized cutting temperature.
- Stabilized temperature and thermal power.

- Protection from inadvertent overheating of sensitive structures.
- Reduced technique sensitivity, while meeting the clinical challenges of existing surgical techniques.

## A TOP Surgery System is Comprised of the Following Elements:

### 1. TOP Tip

A key element of a *TOP Surgery* system is a *TOP Tip*. The *TOP Tip* is designed to continuously convert most of the initial laser power into thermo-optical power. In research, the temperature range of the *TOP Tip* that provides an optimal balance between efficient cutting and patient safety was determined to be between 500 and 900° C. Note that this is the temperature of the tip, not of the tissue! Tissue temperature is much lower during cutting. The *TOP Surgery* system allows the user to set the tip

temperature anywhere in this range. Also, the system has preprogrammed presets for most common dental surgical procedures with optimized temperature settings. This is achieved through the *SureStep* proprietary, computer-controlled tip initiation process.

### 2. SureStep Tip Initiation

*SureStep* is a proprietary, computer-controlled tip initiation process which reproducibly creates a unique three-dimensional initiated *TOP Tip*. The tip

initiation is durable and cannot be easily removed by simply wiping the tip. As an added safety measure, the *TOP Surgery* system also continuously monitors tip initiation quality and provides feedback to the operator. *SureStep* initiation can be performed by a dental professional in-office with a built-in initiation module or at the factory for single use tips.

### 3. Automatic Power Control (APC)

A core functionality of the *TOP Surgery* system is the system's ability to precisely maintain constant temperature at the *TOP Tip* independent of the speed of the surgeon's hand. This is made possible by a proprietary, real-time power and temperature sensing and adjustment system called *Automatic Power Control*. The temperature selected by the operator is maintained independent of the speed of movement through the tissue, or the type and consistency of the tissue. This is a fundamental advancement of the *TOP Surgery* system over any other thermal cutting system available today: *APC* dramatically reduces the effect of movement speed as a variable. The cutting effect and the zone of thermal necrosis are constant for each temperature setting used. This feature significantly reduces the variability of depth of cut and collateral thermal

damage due to changes in speed of movement observed with conventional thermal cutting systems. The learning curve for novices of the *TOP Surgery* system is thereby significantly reduced. When necessary, *APC* delivers more power for fast cutting or cutting of fibrotic tissue, and minimizes power output for reduced cutting speeds to protect the patient.

### 4. AutoStop

As an added safety measure, the *TOP Surgery* system is also capable of sensing a stop in movement and shutting the power down to avoid overheating. This is extremely useful, since in most dental procedures the ability to accomplish smooth continuous movement of the *TOP Tip* is often inhibited by anatomical and positional impediments. If the surgeon has to stop the movement and reposition the tip, or deepen the cut by going over the same area, the points at which the tip movement is stopped can cause substantially more unintended collateral thermal damage if using surgical techniques without the *AutoStop* feature.



Figure 1: A *TOP Surgery* cut is typically clean and deep, with minimal carbonization

In *TOP Surgery*, a precise and constant temperature is maintained at the *TOP Tip*. When the tip touches soft tissue, it rapidly cuts and coagulates the tissue, creating an immediate deep and clean incision. As shown in the histology of a vertical cross-section, the zone of collateral thermal damage is limited to the minimal zone needed to ensure hemostasis throughout the surgery.

## How Is *TOP Surgery* Different from Current Surgical Techniques?

### Contact vs. Non-Contact Cutting

While most surgical instruments touch the tissue to be cut, some laser systems require a certain distance from the surgical site to work. The most prominent non-contact laser devices are  $\text{CO}_2$  lasers and Erbium lasers.

#### 1. Non-Contact Cutting: $\text{CO}_2$ and Erbium

Both  $\text{CO}_2$  and Erbium laser systems have good absorption in soft tissue, i.e. the laser light interacts directly with oral tissue to create the cutting effect. The direct laser light absorption by oral soft tissue also means that laser energy remains localized and

focused, leading to lower heat generation in surrounding tissue and virtually no penetration of laser light into deeper tissue layers. The cuts obtained with these lasers are clean and, depending on the mode used, exhibit a small coagulation zone around the cut with a depth of 20 to 500  $\mu\text{m}$ . Because of an inherent problem of the specific laser wavelengths to travel through standard quartz glass fibers, both  $\text{CO}_2$  and Erbium lasers require complicated light transport systems and optical handpieces with focal point to work in a clinical environment. The handpiece must be held at a certain distance to achieve a good focal point that cuts tissue, similar to using a magnifying glass to focus sunlight. This is the downside of the non-contact technique which is counterintuitive for many dentists. The absence of tactile feedback means that observation alone defines the field of operation, cutting depth and width, which results in a steep learning curve for the clinician.

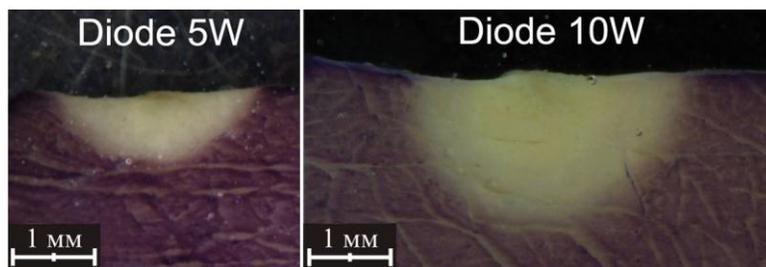
## 2. Contact Cutting

Except for the scalpel, most soft tissue contact-cutting technologies use some form of heat to produce a cut. The electrosurgery device uses an electrical

current to create heat and perform a cut; other variants of the electrosurgery device use radio waves to create heat. Scalpel and Electrosurge have been discussed elsewhere in this paper.

## 3. Near Infrared Lasers: Diodes

Near infrared lasers, such as diode or Nd: YAG lasers, use quartz fibers to transport laser light from the laser source to the target tissue. The fiber walls have a reflective cladding that keeps the laser light inside the fiber; it bounces back and forth from wall to wall, and finally exits at the distal end, or the fiber tip. If the fiber tip has a clean fresh cleave, the laser light will exit freely and penetrate into the tissue below. If the tissue absorbs the laser light well, then most of the light will be absorbed in the top tissue layer and finally lead to a rupture of the tissue, i.e. cutting. If the tissue is a poor absorber of this laser's light, such as oral soft tissue for a diode or Nd: YAG laser, then the light will penetrate into deeper layers of the tissue<sup>3</sup>. This may lead to heat buildup in larger tissue areas and damage sensitive structures underneath the soft tissue layer being irradiated (See Figure 2).



Even at twice the power, diode laser light (in non-contact mode) only penetrates more deeply into tissue and creates more damage, but does not cut soft tissue.

Figure 2 : Tissue interaction for non-contact diode lasers

## Diode Lasers Present a Series of Challenges to Clinicians which Limit their Usefulness as a Surgical Instrument:

### 1. Poor Absorption in Dental Soft Tissue for Diode Wavelength

Diode lasers have poor absorption in soft tissue and would be extremely ineffective cutting instruments if they relied exclusively on the absorption of laser radiation alone to cut tissue (see Figure 2 above).

### 2. Diodes Cut with Heat, not with Light

Diode lasers exhibit a phenomenon called the "hot tip effect". When the tip of an uninitiated laser fiber touches soft tissue and the laser is activated, the laser energy penetrates into the tissue. At the point of contact of the distal end of the fiber with the tissue surface, protein is slowly denatured, becomes

carbonized and turns black. This black denatured protein now clings to the tip and heavily absorbs laser energy, thus heating the tip up to several hundred degrees. When this hot tip touches soft tissue, the heat causes thermo-mechanical tissue cutting and coagulation. But the cutting effect is not constant, because the black deposit on the fiber is continuously scraped away as the fiber passes over tissue, leading to fluctuations in cutting and coagulation power. When there is little or no absorption of diode laser power at the tip of the fiber, the laser power penetrates deeply into tissue, heating up tissue and adjacent sensitive structures. However diode laser power in the range of 1 - 7 Watts simply does not have enough power to cut soft tissue with direct laser light (see Figure 2 above). Standard diode lasers cut exclusively due to the hot tip effect.

### 3. Diode's Tip Temperature Fluctuates Wildly

Diode laser manufacturers have taken notice of this issue and now suggest initiating laser fibers using cork or articulating paper. These non-standardized techniques do not guarantee consistent initiation, nor does the initiation last longer than a few seconds

while cutting tissue. The diode relies heavily on constant reinitiating by denatured protein to work as a cutting instrument, resulting in tremendous fluctuations of cutting temperature, cutting efficiency and coagulation zone during a procedure.

### 4. Diode's Inconsistent Cutting = Snag, Drag, and Thermal Damage

This inconsistent cutting effect is the primary reason for frustrations with the diode laser's ability to cut soft tissue and has a direct and obvious impact on cutting performance and collateral thermal damage with these systems. Uncontrolled collateral thermal damage is the visible result of temperature fluctuations; the time on tissue is variable, but is always longer than with all other heat-based techniques (see Figure 3 below). Even an experienced user cannot prevent this from happening because it is an inherent deficiency of near infrared lasers. Diode laser manufacturers have proposed procedures for tip initiation that accelerate the hot tip creation, but do not guarantee complete initiation or consistency over time.

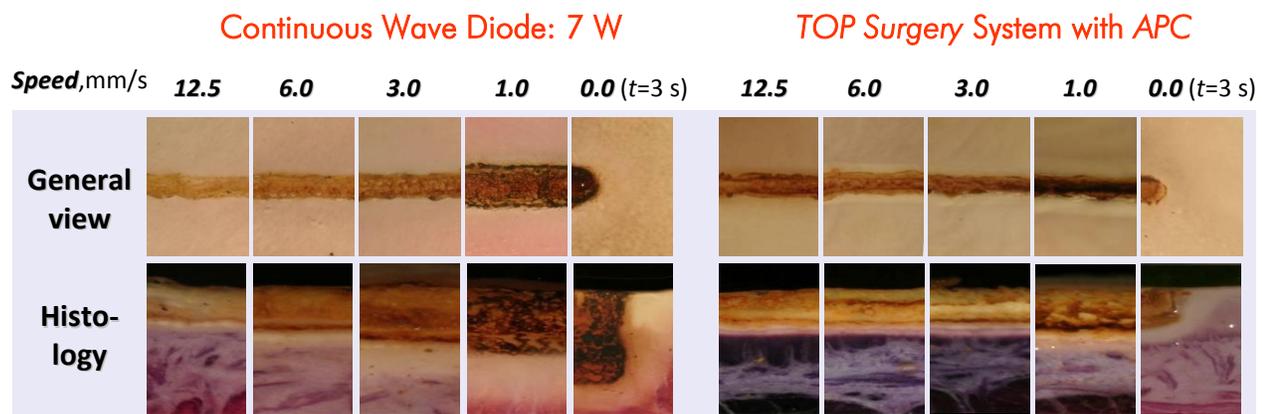


Figure 3: Effect of Cutting Speed on Collateral Thermal Damage

**Note:** The images above<sup>1</sup> represents a series of photos (top row) and histology (bottom row) of soft tissue cutting at five different speeds of movement, from 12.5 mm per second to 0 mm per second (stationary) performed with TOP Surgery and a traditional diode laser. Note that as the speed decreases, the level of collateral tissue damage and carbonization increases sharply for diode lasers, while it remains essentially the same for the TOP Surgery system. (NBTC viability staining was used, so stained areas show live cells, while cells in white areas are dead.)

## TOP Surgery System

A TOP Surgery system uses a handpiece with a unique TOP Tip to cut soft tissue by direct contact. Each TOP Tip is initiated using a computer-controlled proprietary SureStep initiation process (see Figure 4 below). The thermal power at the tip is continuously monitored and adjusted by APC to ensure that the cutting parameters are constant. The tip glides smoothly over tissue in a way that is similar to a scalpel, and provides a precisely controllable cutting experience. TOP Surgery allows for the shortest time-on-tissue of all heat-based systems. The cuts obtained are clean and generally do not exhibit signs of burning or carbonization. Thermal collateral damage is precisely controlled and limited.



Figure 4: Fiber Initiation Examples

### Comparison of TOP Surgery and Conventional Diode

Feature	TOP Surgery	Diode Laser
SureStep computer-controlled tip initiation	✓	✗
Laser light conversion to thermal power	<b>Maximized</b> (High)	<b>Variable</b> (Poor)
Continuous monitoring of initiated tip's quality	✓	✗
APC allows to program cutting temperature at the tip and continuously adjusts power to maintain set tip temperature and coagulation zone	✓	✗
AutoStop detects movement stop and shuts down laser to prevent tissue damage	✓	✗

## Concluding Remarks; Clinical Outlook

*TOP Surgery* has the potential to revolutionize soft tissue surgical procedures and make them more accessible to a multifaceted group of dental practices. *TOP Surgery* avoids most of the pitfalls that have prevented dental practitioners from integrating a wider range of soft tissue procedures into their daily routines. The typical barriers of soft

tissue procedures such as bleeding, collateral thermal damage, imprecision in cutting, slow, intermittent or inconsistent cutting, and the steep learning curve associated with some recent instrumentation have been eliminated with the easy-to-learn and easy-to-use *TOP Surgery* technology.

### 1. Cuts soft tissue quickly and smoothly with pinpoint laser precision

- Cuts like a CO<sub>2</sub> laser but with greater control and tactile feedback
- Easy-glide cutting without drag, snag or stop
- Clear field of operation without bleeding or charring
- Performs procedures that are challenging for diodes such as operculectomy, frenectomy, implant exposure with ease
- Troughing procedures done in seconds without bleeding or pain

### 2. Minimizes thermal damage; preserves tissue

- Extremely precise and easy contouring of soft tissue in the aesthetic zone
- More tissue preserved for histopathology in surgical excisions and biopsies
- Minimized risk of overheating of implants, connective tissue or osteonecrosis
- No scarring or gingival recession due to minimal thermal damage
- Minimal post-operative discomfort and shortest healing time of any thermal cutting device

### 3. Easy to learn and safer to use

- Replaces multiple technical parameters (e.g. Watts, Hertz, Pulse duration, etc.) with one parameter – Temperature
- Minimizes cutting speed as a variable
- Minimal need for anesthesia (topical anesthetic is sufficient in the majority of cases, infiltration instead of a block for more challenging cases may be required)
- Safer and more forgiving to use compared with any other surgical device: scalpel, Electrosurge, CO<sub>2</sub> or diode

A future White Paper will evaluate the clinical implications of *TOP Surgery* and look at some examples of its use for key dental procedures.

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