Dr. Peter Vitruk held a variety of laser physics R&D positions in 1990s around the globe (The Academy of Sciences in the former USSR; Heriot-Watt University, U.K.; Synrad Inc, U.S.; Luxar Corp, U.S.; Lumenis Inc, U.S.) prior to co-founding the Luxarcare-Aesculight-LightScalpel group of laser companies in mid-2000s in Seattle. His work contributed to the development of high power RF excited CO2 lasers and atomic Xe lasers. His most recent interests include the physics of soft tissue surgery and dentistry. Vitruk is a member of The Institute of Physics, UK, Diplomate of the American Board of Laser Surgery, U.S., director of Laser Physics & Safety Education at the American Board of Laser Surgery, U.S., and a member of Science & Research Committee, Academy of Laser Dentistry. U.S. He can be reached at pvitruk@lightscalpel.com.

Introduction

The “sound scientific basis and proven efficacy in order to ensure public safety” is one of the main eligibility requirements of the ADA CERP recognition standards and procedures.1 The scientific foundation for understanding soft-tissue laser ablation and coagulation is based on the soft tissue’s light scattering and absorption spectra.2–7

Unfortunately, some laser dentistry educational programs and publications include misinterpretations about soft- and hard-tissue laser science and safety. Such misrepresentations partially take their origin in the laser dentistry curriculum guidelines, which date back to the early 1990s.8

In this article, I’ll discuss some important laser-tissue interaction concepts—ones that are missing from the vocabulary of the Laser Dentistry Curriculum Guidelines and Standards,8 namely absorption spectra,2–7 hot glass tip9–11 and plasma plume.12,13
Absorption spectra and soft-tissue laser ablation

A chromophore is defined as a molecule or substance capable of absorbing specific laser wavelengths. The main chromophores for ablation and coagulation of oral soft tissue are known to be hemoglobin, oxyhemoglobin, melanin and water. These four chromophores are distributed unevenly within oral tissue. Water and melanin, for example, reside in the 100–300-µm-thick epithelium; water, hemoglobin and oxyhemoglobin reside in the subepithelium (lamina propria and submucosa).

Each of the oral soft tissue’s four main chromophores has a known optical absorption coefficient spectrum. Fig. 1 presents absorption spectra for the different chromophore concentrations of water, melanin, hemoglobin (Hb) and oxyhemoglobin (HbO₂). Light scattering by the soft tissue is insignificant at erbium and CO₂ laser wavelengths. Light scattering by the soft tissue dominates over absorption at near-IR diode and Nd:YAG laser wavelengths, and facilitates a wider-spread coagulation and thermal damage.

Fig. 1 illustrates how the oral epithelium (e.g., at 75 percent water and 2 percent melanin) absorbs the Nd:YAG and diode laser wavelengths in the 800–1,100nm range 100–1,000 times less efficiently than the CO₂ and erbium laser wavelengths. Fig. 1 also illustrates that the near-infrared Nd:YAG and diode laser wavelengths in the 800–1,100nm range are absorbed by the oral subepithelial soft tissue (e.g., at 75 percent water and 10 percent blood) approximately 1,000–10,000 times less efficiently than the CO₂ and erbium laser wavelengths.

The shallower the absorption depth (i.e., stronger absorption), the less energy is required to ablate the tissue within the exposed volume. Therefore, the mid-infrared erbium and infrared CO₂ laser wavelengths are highly efficient and spatially accurate laser ablation tools because of their very strong absorption by the soft tissue. The deeper the absorption depth (i.e., weaker absorption) and the stronger the scattering, the more energy is required to ablate the tissue. Therefore, the near-IR diode and Nd:YAG laser wavelengths are highly inefficient and spatially inaccurate photothermal laser ablation tools because of their weak absorption by the soft tissue.

Hot glass tip

The near-infrared wavelengths of dental diode lasers cannot photothermally ablate soft tissue, except for high-melanin-content epithelium. Instead, the near-infrared diode laser beam heats the charred distal end of its fiber optic glass tip to 500–900 degrees Celsius. The glowing hot glass tip, then, conducts heat to the soft tissue.

Soft tissue is burned on contact with the hot glass tip. The efficacy of this device-tissue interface (charred hot glass surface) is highly dependent on multiple factors:

- The user’s technique and skill in charring the glass tip.
- The user’s hand speed and tip-tissue contact duration.
- Degradation of the glass tip’s char, which reduces tip temperature and increases the near-infrared-induced subsurface thermal-induced tissue necrosis, and leads to mechanical tearing of the tissue by the glass tip’s edges.
- Biocompatibility and sterility of the char that’s produced by burned ink or corkwood when applying the hot tip to the soft tissue.
• Biocompatibility of the hot glass and its cladding materials at 500–900 degrees Celsius operating temperatures when applying the hot tip to the soft tissue.19
• Biocompatibility of fractured glass produced by the thermal gradient-induced fractures of the hot glass tip at 500–900 degrees Celsius operating temperatures.21

Plasma plume

The ease of the soft-tissue CO₂ laser surgery (Fig. 2a) is largely based upon the low-temperature water vaporization at 100 degrees Celsius. The collateral damage in the heat-affected zone is much appreciated coagulation and hemostasis. In some hard-tissue cutting applications, however, a very high ablation temperature (approximately 5,000 degrees Celsius) could result in extremely bright thermal radiation (Figs. 2b and 2c).

The hard-tissue laser’s “beam interactions with the hard tissue can generate intense plasma emissions … requiring suitable optical filtering for direct viewing,” while “plasma emissions … may contain sufficient UV,” requiring the UV exposure limits to be addressed. Also, the high brightness of the hydroxyapatite plasma in the visible spectrum (Figs. 2b and 2c) may interfere with the laser’s pointing accuracy by affecting the target’s visibility, because of the enamel’s high translucence and light scattering.12, 13, 22, 23, 24

Summary

The science-based absorption properties of the soft tissue can adequately explain the different ablative and coagulative properties of practical lasers at different wavelengths. Such explanation depends critically on the concentration of the chromophores in the tissue. Similarly, the science-based absorption properties of the soft tissue explains that the only practical modality of soft-tissue cutting with practical diode and Nd:YAG lasers is the “hot tip.”

Last, but not least, the nonbeam laser hazards and respective safety measures need to be addressed in view of the optical emission spectrum of the plasma plume created during the hard-tissue cutting with the 9,300nm lasers. All the above are absent from the laser dentistry education guidelines and standards, but are critically important to be a part of the CERP-approved laser dentistry education in compliance with the ADA CERP standards.1

Continued on p. 4
The shallower the absorption depth (i.e., stronger absorption), the less energy is required to ablate the tissue within the exposed volume.

References