by Peter Vitruk, PhD, MInstP, CPhys, DABLS

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. The scientific foundation for understanding soft-tissue laser ablation and coagulation is based on the soft tissue’s light scattering and absorption spectra.

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.

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, namely absorption spectra, hot glass tip and plasma plume.

A review of dental laser education standards

Laser Education, Science and Safety

by Peter Vitruk, PhD, MInstP, CPhys, DABLS

牙科激光教育、科学与安全

牙科激光教育标准的回顾

介绍

“科学的坚实基础和经过验证的有效性以确保公众安全”是ADA CERP认可标准和程序的主要合格要求之一。软组织激光消融和凝固的科学基础基于软组织的光散射和吸收光谱。

不幸的是，一些激光牙科教育项目和出版物包含了对软组织和硬组织激光科学和安全的误解。这种误解部分源于激光牙科学课程指南，这些指南可以追溯到20世纪90年代初。

在本文中，我将讨论一些重要的激光-组织相互作用概念——这些概念在激光牙科学课程指南中缺失，例如吸收光谱、热玻璃尖端和等离子体喷射。

牙科激光教育标准的回顾

Peter Vitruk博士，拥有激光物理学和研究背景，为1990年代全球（前苏联科学院、英国 Heriot-Watt大学、美国 Synrad Inc、美国 Luxar Corp、美国 Lumenis Inc）的多个研发岗位。他参与了高功率射频激发CO₂激光和原子Xe激光的发展。他的最近兴趣包括软组织牙科手术和牙科的物理学。Vitruk是英国物理学会成员，美国牙科激光学会特许成员，美国牙科牙科手术学会成员。他还是美国牙科牙科教育委员会成员。他可以联系到pvitruk@lightscalpel.com。
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 sub-surface 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.

**Fig. 1.** Optical absorption coefficient spectra at different histologically relevant concentrations of water, hemoglobin (Hb), oxyhemoglobin (HbO₂), and melanin based on data from References 2–7. Logarithmic scales are in use.
• 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

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

References