The use of low-level lasers (LLLS) as a therapeutic modality has been widespread in countries outside the United States since the early 1970s.1 In 2002, the FDA cleared them for adjunctive use in the temporary relief of hand and wrist pain associated with carpal tunnel syndrome and in providing temporary relief of minor chronic neck and shoulder pain of musculoskeletal origin. The clearance by the FDA made LLL an available tool for use by allied health professionals in the United States.2,3

Lasers and the Electromagnetic Spectrum

Evidence has shown that photons emitted from LLL with wavelengths in the red and near-infrared range are capable of stimulating receptors in biological tissues, with the stimulation being therapeutically beneficial.4 Originally, this effect was termed biostimulation, but because inhibitory effects have also been observed with LLL application, a more appropriate term is biomodulation.5

One of the key criteria to successfully invoking a photobiomodulatory effect is the appropriate application of energy. If excessive amounts of energy are applied, tissue destruction occurs, as seen with surgical lasers. Surgical lasers are thermal in nature, meaning that their application results in a heating effect. They also typically have power outputs > 500 mW.6 In contrast, lasers that are used in the process of photobiomodulation are nonthermal, or cold, lasers with typical power outputs < 500 mW.6 Because of the lower power output these lasers are known as low-power or low-level lasers.

Another key to successfully invoking a therapeutic effect with the application of LLL therapy (LLLT) is the wavelength of the laser. Wavelength is critical for two primary reasons: It determines receptor stimulation, which in turn determines the biological response, and it determines the depth of photon penetration.7 Typically, LLLs have wavelengths in the range of 600–1,000 nanometers (nm). Because this range overlaps with the visual spectrum for humans, LLLs with wavelengths closer to 600 nm will be visible as red light, whereas LLL with wavelengths closer to 1,000 nm will be invisible because they are in the near-infrared range, which is outside of the normal visual spectrum for humans.8 The most researched and most commonly used wavelengths in LLLT are the following:

- 632.8-nm helium-neon (HeNe)
- 820- to 830-nm gallium-aluminum-arsenide (GaAlAr)
- 904-nm gallium arsenide (GaAs)8

Currently, the FDA has cleared the marketing of LLL with wavelengths of 635 nm and 830 nm for the relief of hand and wrist pain associated with carpal tunnel syndrome and for the relief of minor shoulder and neck pain of musculoskeletal origin.2,3 Once a health-care clinician has purchased an LLL, however, he or she can use it to treat various medical conditions as defined by the medical profession.
practice act of the state in which he or she practices. Clinicians should be cautioned that they could still be held liable for any damages that might result from the improper use of LLL.

**Photobiomodulatory Effects of Low-Level Lasers**

In a recent article, Karu et al. reported that photons are absorbed by photoreceptors in cells. Photon absorption leads to a shift in the molecular configuration of the photoreceptor with an associated alteration in the molecular processes of the cell. The alteration in the photoreceptor’s function is the primary reaction, and the subsequent alterations in cellular functions and cellular signaling are secondary reactions. This in turn results in an increase in mitochondrial oxidative metabolism with an ensuing increase in ATP production. Increased ATP production leads to an increase in cellular metabolism and function. These changes lead to an increase in various metabolic processes such as the synthesis of DNA, RNA, proteins, enzymes, and other products needed to repair or regenerate cell components. Additional changes include fostering cell mitosis or cell proliferation and restoring homeostasis. In conditions of cellular pathology, the previously mentioned cellular reactions and processes are inhibited, and as a result, LLLT will have much more pronounced effects because of the reduced cellular functioning. In cases in which the cellular environment is optimal or near optimal (nonpathological) the effects of LLLT will not be as pronounced. In essence, LLLT functions to normalize cellular function. This is important to understand because it provides an explanation for some of the varying results of LLLT in the literature.

Through the enhancement of mitochondrial function, the resultant increase in ATP production, and alterations in various other cellular functions, LLLT has been found to enhance recovery and decrease symptoms associated with numerous pathological conditions. Research has found that through various mechanisms, LLLT can effectively enhance wound healing, increase the tensile strength and stiffness of healing ligaments, improve tendon healing, and decrease pain. Overall, studies have found that LLLT is effective in reducing pain and increasing functional ability in numerous musculoskeletal conditions including carpal tunnel syndrome, low back pain, osteoarthritis, and myofascial pain. A recent review of the literature indicated that LLLT seems to be an effective modality to reduce pain originating from chronic joint disorders.

**Treatment Parameters**

Because LLL beams are a component of the electromagnetic spectrum, clinicians must understand some basic laws before they can effectively and appropriately use LLL. According to the law of Grothus-Draper, when photons emitted from a laser encounter a change in density—in the case of therapeutic applications this is most often the different layers of tissue (skin, fat, muscle, ligament, and bone)—the photons will be reflected, refracted, absorbed, or transmitted. In addition, the cosine law states that the amount of reflection and refraction is greater when the treatment head is not held perpendicular to the surface being treated. The more energy is absorbed and scattered as a result of reflection and refraction, the less energy is available to be transmitted to deeper tissues, and therefore less penetration occurs.

The primary determinant of depth of penetration in LLLT is wavelength. Lasers with shorter wavelengths have less depth of penetration than do lasers with longer wavelengths. When describing depth of penetration one can break the effects down into direct and indirect effects. Direct effects are a result of photon absorption by excitable structures, and indirect effects are lessened responses that occur deeper in the tissues. HeNe lasers (wavelength 632.8 nm) have a direct penetration of 2–5 mm and an indirect penetration of 8–10 mm. GaAs lasers (wavelength 904 nm) have a direct penetration of 1–2 cm and an indirect penetration of up to 5 cm. Other factors that play a role in determining depth of penetration are the skin’s melanin content and the amount of blood perfusion to the area being treated. Both melanin and hemoglobin absorb photons and therefore play a role in determining the number of photons available for transmission to deeper tissue layers.

Although wavelength is probably the most important factor in determining depth of penetration, there must also be a driving force. The driving force is the power or amount of energy that is being applied. A good anal-