Original Contributions

A pilot study of laser energy transmission through bone and gingiva

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ABSTRACT

Background. The use of low-level laser therapy is growing in the field of dentistry especially in orthodontics to speed up tooth movement and in implantology to aid osseointegration. In these dental applications, the laser energy needs to penetrate through the periodontium to the target site to stimulate photobiomodulation. The percentage of energy loss when laser is transmitted through the periodontium has not been previously studied. With the use of an 808-nanometer diode laser, the aim was to investigate the percentage loss of laser energy when transmitted through the periodontium to the extraction socket.

Methods. The percentage energy loss of an 808-nm diode laser through the periodontium was measured in 27 tooth sockets by using a specifically designed photodiode ammeter.

Results. For each millimeter of increased bone thickness there was 6.81% reduction in laser energy (95% confidence interval, 5.02% to 8.60%). The gingival thickness had no statistically significant effect on energy penetration.

Conclusion. Energy penetration depends markedly on bone thickness and is independent of gingival thickness.

Practical Implications. To the best of the authors' knowledge, this study is one of the first to investigate laser penetration through the periodontium. Evidence from this study showed that laser energy penetration through the periodontium is markedly affected by bone thickness but less so by gingival thickness. Clinicians need to be aware of the biological factors that could affect laser energy penetration to the target site and adjust their laser dosages accordingly. These findings may guide dental practitioners in selecting the appropriate laser dosage parameters for low-level laser therapy.

Key Words. Alveolar bone; diode laser; energy loss; gingival tissue; penetration; periodontium.

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Low-level laser therapy (LLLT) or photobiomodulation is a promising technique at the forefront of medicine and dentistry. The use of low-level lasers (< 500 milliwatt; < 35 joules/square centimeter; wavelengths of 600-1,300 nanometers) in the treatment of wounds, soft-tissue injuries, and pain management was developed in the 1960s and has escalated in the past decade.[1,2] Photobiomodulation is defined as a form of light therapy that uses nonionizing forms of lasers or light-emitting diodes in the visible and infrared spectrum. It is a nonthermal reaction that triggers endogenous chromophores to stimulate photochemical and photophysical effects to alter various biological processes.[3] Photobiomodulation produces therapeutic benefits that encompass but are not restricted to the promotion of wound healing and tissue regeneration, immunomodulation, and reduction of pain or inflammation.[4-6]

The use of LLLT in dentistry is growing in popularity because of its biostimulatory effects, noninvasive manner, and ease of use. In dentistry, LLLT has been suggested for treatment of aphthous ulcers,[7] dentinal hypersensitivity, periodontitis,[8] and acceleration of osseointegration after implant placement,[9] as well as an analgesic.[10] In the field of orthodontics, LLLT was found to accelerate bone regeneration in the midpalatal suture area after rapid maxillary expansion,[11] reduce orthodontic treatment time and pain,[12] and enhance the stability of orthodontic mini-implants.[13] Because low-level laser irradiation was found to enhance osteoblast proliferation,[14] interest is growing in the effectiveness of LLLT in wound healing of extraction sockets[15] and the stimulation it may provide in bone-implant interactions by improving bone functional attachment and acceleration of bone healing to titanium implants with minimal adverse effects.[16]

Gallium-aluminum-arsenide (GaAlAs) diode lasers were found to have a positive effect in bone formation after tooth extraction in rabbits with diode laser—treated sockets, resulting in faster maturation of newly formed bone. In addition, there was greater density and overall volume of trabecular bone compared with controls.[17] In the rat extraction model and with the use of microcomputed tomography, histomorphometry, and real-time polymerase chain reaction, it was indicated that high-frequency pulsed LLLT enhanced healing of both hard and soft tissues by increasing bone mineral content, bone volume, bone mineral density, and the levels of bone formation indicators such as osteocalcin messenger RNA and the number of cells positive for proliferating cell nuclear antigen.[18]

The effects of LLLT on titanium surfaces were studied in vitro and in vivo, and researchers of many studies have reported beneficial effects. Cell adhesion on smooth and rough titanium surfaces was statistically significantly improved in neodymium-doped yttrium aluminum garnet (1,064-nm) laser-irradiated cell cultures for both types of titanium surfaces by exerting a positive effect on the proliferation and differentiation of MG-63 osteoblastic cells.[19] When the effects of LLLT with a diode GaAlAs on the healing and attachment of titanium implants, which were inserted into New Zealand rabbit femurs, were evaluated, it was found that irradiated implants exhibited histomorphometrically stronger attachment, but removal torque and resonance frequency analysis did not find any differences for controls.[20] Even though animal and laboratory studies have indicated a positive effect of LLLT on implant osseointegration, the plethora of protocols and types of lasers used, combined with the reduced number of existing human studies, reveal a controversy in available results and the lack of unbiased evidence in the effects of LLLT in the quality and acceleration of osseointegration.[21]

Lasers with different wavelengths can penetrate into human tissues at different depths. Red laser penetrates deeper than violet, blue, green, or yellow lasers. Infrared and near-infrared lights are invisible but were found to penetrate human tissues deeper than the visible red light.[22,23] In addition, the penetration depth of laser radiation relies on the absorption and scattering characteristics of the irradiated tissue.[24] Direct measurement of low-level laser penetration depth was reported in few human studies. Although the interest in the use of LLLT in dentistry has increased substantially in the past decade, the exact penetration depth of LLLT in human alveolar bone and gingiva remains unspecified. Whether laser energy penetrates through gingival and bone tissue to reach the intended target site has not been investigated yet. Evidence of the depth of penetration of low-level laser energy in vivo is of great value for clinicians to evaluate the suitability of LLLT as a treatment modality in various fields in dentistry such as alveolar extraction healing and grafting, implant osseointegration, and orthodontics.

Our aim was to provide a novel method to measure the percentage of energy loss of an 808-nm diode laser through the periodontium (defined as alveolar bone and gingiva) to the extraction socket.

METHODS

Sample

Sixteen patients (8 males and 8 females; mean [standard deviation] age, 16.5 [1.2] years), who required maxillary first premolar extractions before orthodontic treatment, were selected for this study, and a total of 27 suitable sockets were investigated. None of the patients had excessive gingival melanin concentration that could potentially affect light absorption. Patients were recruited from the Sydney Dental Hospital, Sydney, New South Wales, Australia, from October 2014 through December 2014, and excellent oral hygiene was established before the commencement of the experiment to ensure healthy periodontal conditions. Informed consent was received from the participants. Ethics approval was obtained by the Royal Prince Alfred Hospital Ethics Committee (X14-0200 HREC.14/RPAH/263).

Equipment

An 808-nm gallium arsenide diode laser (Klas-DX6182, Konftec) was used in this experiment. The continuous laser produced a power output of 0.18 watts. The laser energy was delivered to the

ABBREVIATION KEY

GaAlAs: Gallium-aluminum-arsenide.
LLLT: Low-level laser therapy.