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Evaluation of Effective Transmission of Light Through Alveolar Bone: A Preliminary Study

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Abstract

Introduction: The aim of the present study was to determine the effective transmission of 660 and 780 nm lasers through mandibular and maxillary alveolar bones in the buccal-lingual/ palatal direction.

Methods: The laser probe was positioned in direct contact with the surface of the anterior, middle and posterior regions of each bone (5 dried maxillae and 5 mandibles) and the power meter was positioned on the bone wall opposite to the radiated wall for the measure of the remaining energy passing through the bone tissue. Ten measurements were performed with each laser at each irradiated point.

Results: Transmitted power was significantly higher in bones irradiated with 780 nm laser. Tendencies toward greater average power transmitted in the anterior region of both bones at both wavelengths were also observed.

Conclusion: Dosimetry and the choice of light source may be adjusted according to the anatomic region of the alveolar bone to be treated.

Keywords: bone; lasers; laser therapy.

Introduction

Low intensity laser therapy (LILT) has been used and researched in health sciences in order to reduce signs and symptoms related to inflammatory conditions and both facilitate and accelerate repair of injured tissues.[1-5] Low-level therapeutic light (laser or LED) is normally administered at wavelengths ranging from 600 to 1000 nm, an energy density ranging from 1 to 20 J/cm^2 and power density ranging from 5 to 50 mW/cm^2 or higher when an analgesic effect is desired.[1,3,4]

Despite the many positive reports regarding the results of LILT in clinical trials, in vitro investigations and animal studies, its use and indication remain controversial.[1-4] This controversy is related to partial knowledge on the mechanisms of action, the considerable variability in dosimetric parameters, inappropriate parameter choices, the biphasic or even triphasic nature of tissue and cell responses to light as well as the lack of information on interactions between the different kinds of therapeutic light and the target biological tissue.

The effect of light on a given tissue or cell depends on photon absorption by molecular receptors, denominated photoreceptors.[2,6] However, when light reaches a surface, its energy is absorbed, reflected and scattered. Thus, only part of the incident energy is transmitted.[2,7] Light penetration and distribution depend on the wavelength as well as the biochemical composition and anatomy of the irradiated tissue.[8,9]

The aim of the present study was to evaluate the effective transmission of red (660 nm) and infrared (780 nm) low intensity laser through the anterior, middle and posterior regions of human maxillary and mandibular alveolar bone (in the buccal-lingual/palatal direction) to gather information that may help to determine more efficient parameters for the use of LILT in postoperative oral surgery involving bone tissue.

Methods

Five maxillary and five mandibular bones (without the surrounding soft tissues) from the collection of anatomic specimens of our university were used. In order to measure the effective transmission of red (660 nm) and infrared (780 nm) low intensity laser through the anterior, middle and posterior regions of maxillary and mandibular alveolar bone, the lasers' head were positioned in direct contact with the surface of the anterior (incisor area), middle (premolar area) and posterior (molar area) regions of each bone (in the buccal-lingual/palatal direction). In each site, the lasers were placed in the apical region at the end of the dental alveoli, not reaching the

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roots. The sensor (area: 2,84 cm^2, Coherent Inc., Portland, Oregon, USA) of the power meter (Field Mate, Coherent Inc.) was positioned in direct contact with the surface on the bone wall opposite to the radiated wall to measure the energy remaining after passing through the bone tissue (Figure 1).

Red (λ = 660 nm) and infrared (λ = 780 nm) diode lasers (MM Twin Laser Optics, São Paulo, SP, Brazil) were used with an output power of 40 mW. A single operator performed the irradiations in the same day. Each measurement took approximately 10 seconds. Ten measurements were performed with each laser at each irradiated point, thus the overall irradiation duration was 100 seconds for each site of each sample. All measurements were performed in the dark to avoid interference from other light sources. Table 1 shows in details the irradiation and spectral parameter used in this work.

Statistical Analysis

The 10 measurements at the each site were used for the statistical analysis. The Shapiro-Wilk test was used to assess the normality of the data. Friedman's analysis of variance (ANOVA) and Wilcoxon signed-rank tests were used to compare the results.

Results

The mandible (anterior and middle regions) and maxilla (middle and posterior regions) groups did not present normal distribution. Thus, the data is presented using median and quartile values (Figure 2).

In both the maxilla and mandible, the transmitted power (in buccal-lingual/palatal direction) was significantly higher in the three anatomic regions studied (anterior, middle and posterior) when irradiation was performed with 780 nm laser in comparison to 660 nm laser ($P = 0.0313$ for all comparisons, Wilcoxon).

In the analysis of the three anatomic regions in the same bone, the mean power transmitted was significantly higher in the anterior region ($P < 0.05$) in comparison to the posterior region at both wavelengths in both the maxilla and mandible (Friedman's ANOVA test). No significant differences were found in the comparison of the other regions. No statistically significant difference was observed in the transmission between the maxillary and mandibular bones at both wavelengths.

Discussion

When light passes through biological tissues, it undergoes five main processes: reflection, refraction, scattering, absorption and transmission. In reflection, the light is send back to the incident medium (usually air). Refraction and scattering, although different in nature, only change de direction of the photon. Absorption is the only phenomena that actually transfers the photon energy to the medium and transmitted power is the remaining power after the passage of the light through tissue and is related to absorption, reflection and scattering phenomena.[2,7,10] Transmitted power also depends on the wavelength employed; the morphology; as well as the target tissue and its composition (its chromophores).[8,9] Thus, there is a need to characterize the optical properties of different tissues to gain a better understanding of the interaction with light sources of different wavelengths.

However, due to intrinsic differences and the morphological variability of bones between individuals and even anatomic regions of the same bone, the simple characterization of the optical properties of bone (absorption and scattering coefficients) is not sufficient to determine the depth of light penetration in these tissues. Studies on the

Table 1. Irradiation and Spectral Parameter Used in This Work

Parameter	IR	Red
Center wavelength (nm)	787	660
Spectral bandwidth (FWHM) (nm)	0.64	0.71
Operating mode	Continuous wave	
Average radiant power (mW)	40	
Polarization	Random	
Beam profile	Multimode	
Beam spot size at target (cm^2)	0.04	
Irradiance at target (mW/cm^2)	1000	
Exposure duration (s)	100	
Radiant exposure (J/cm^2)	100	
Radiant energy (J)	4	
Number of sites irradiated	1	
Application technique	Contact, perpendicular to the bone's surface	

Figure 1. Laser Placed in the Apical Region at the End of the Dental Alveoli and the Sensor Positioned in Direct Contact With the Surface on the Bone Wall Opposite to the Radiated Wall.

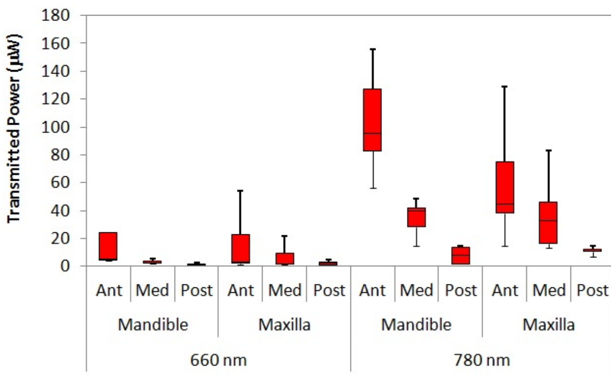

Figure 2. Values of the Power (µW) Transmitted in All Groups.

amount of light that is effectively transmitted through different regions of each bone carry information regarding light penetration in the tissue.

It is therefore necessary to perform detailed studies on the amount of light that is effectively transmitted through different regions of each bone. The optical properties of a number of soft tissues and human organs, such as skin, subcutaneous, adipose and mucosal tissues[11-14] as well as some human and animal bones[15,16] have been described. However, the optical properties and effective transmission of different wavelengths of light have not previously been described in alveolar bone. The alveolar tissue is a ridge on the surfaces of the inferior maxillae and the superior mandible, composed by compact and cancellous bone (inner part) where teeth are lining in sockets called alveoli. The present study characterized the transmission of two lasers commonly used in dental clinics[5] through the alveolar bone of human maxillae and mandibles.

The average transmitted power was 14-fold greater in the three anatomic regions (anterior, middle and posterior) of the bones studied when irradiation was performed with 780 nm laser in comparison to 660 nm laser. This is likely related to this greater penetration depth of infrared wavelengths in comparison to the red region of the electromagnetic spectrum.[9,10,17] Thus, by applying infrared light, more photons would reach deeper sites of the bone, increasing the amount of energy available for the deep tissue.

Comparing the three anatomic regions, deeper light penetration was found in the anterior region, followed by the middle and posterior regions, with a significant difference between the anterior and posterior regions in both bones evaluated. This phenomenon occurred independently of the light source and bone, and depends mainly on the thickness of the tissue, regardless of its composition; which modifies the behavior of light.[10]

Although trabecular is thicker in the posterior region in comparison to the anterior region in both the maxilla and mandible[18] and bone being denser in the anterior mandible, followed by the anterior maxilla, posterior mandible, and posterior maxilla,[19,20] the bone thickness increases from the region of the central incisors to molars region in maxilla and mandible.[21,22] It has been reported[18] that the average thickness of the *edentulous* maxilla is 1.69 mm in the posterior region, 1.43 mm in middle and 1.04 mm in the anterior maxilla. While the mandibule thickness ranges from 2.06 mm in the posterior region, 1.78 mm in the middle region and 1.36 mm in the anterior region, corroborating the data of highest energy transmitted in the anterior region of both bones.

Thus, it may be appropriate to adjust the power for treatment with LLLT in the anterior and posterior regions of alveolar bone and to choose infrared laser when the treatment's target is deep inside the bone.

Conclusion

The present findings provide initial information regarding the behavior of red and infrared lasers on alveolar bone in the buccal-lingual/palatal direction. Logically, these data should be complemented with the characterization of the optical properties of alveolar bone, blood and soft tissues. However, one may assume that dosimetry and the choice of light source should be adjusted according to the anatomic region of the alveolar bone to be treated.

Ethical Considerations

This study was independently reviewed and approved by our University Ethics Committee under process number 69 642 (Aug, 2012).

Conflict of Interests

Authors declare that they have no conflict of interests.

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