BONE REGENERATION EFFECT OF LOW LEVEL LASERS INCLUDING ARGON LASER

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Introduction

In the recent medical application of lasers their stimulative effects on biological functions have been especially noticed and many useful therapeutic effects have been applied. The therapeutic effect of lasers on bone diseases is very important and has attracted some attention.¹⁻⁴ The authors' clinical application of the Nd:YAG laser has already revealed the bone regeneration effect of lasers.⁵⁻⁷

Following this, the authors have studied the bone healing effects of low power level lasers including the argon ion laser in low incident energy application. This paper reports the results in the authors' study on the bone regeneration effects in low reactive level laser therapy (LLLT) including a low energy level argon ion laser, not usually considered as an LLLT system.

Therapeutic Effects in LLLT for Alveolar Bone Diseases

LLLT for Alveolar Wounds Following Tooth Extraction

Method. Alveolar bone wounds following tooth extraction was exposed to a low power laser and the wound healing was evaluated macroscopically and roentgenographically. The GaAlAs diode laser system (wavelength 830 nm, maximum output power 20 mW) and the HeNe laser system wavelength 632.8 nm, output power 6 mW) were used in this

study. The above-mentioned laser beam was applied to the alveolar bone socket after tooth extraction for 3–5 min at a power density of 0.19–0.76 W/cm² in the HeNe laser and 0.64–2.56 W/cm² in the diode laser in continuous wave mode for 3–5 min per session of this laser treatment. The LLLT was performed one time a day and continued for several sessions depending on the therapeutic requirement in each case. The patients with simultaneous extraction of more than two different teeth were selected as subjects in this study, one of which extraction site was selected as the unlased control to the lased wound. The healing process of the lased wound and the unlased wound (control) were comparatively observed on a series of roentgenograms following tooth extraction to evaluate the bone healing effect of the lasers.

Results. Figure 1 shows the roentgenographic follow-up for the alveolar bone wound healing in following extraction of the right upper premolar (4J) and the left upper first premolar (14). The two different teeth were extracted simultaneously. The extraction socket of 4J was not given any laser treatment but the wound of 4 was exposed to GaAlAs diode laser of 20 mW output power at a spot size of 2 mm in diameter (0.64 W/cm²) for 5 min (192 J/cm²) in every session of treatment after operation. Comparative observation of the bone healing of the lased wound (14) and that of the unlased wound (4J) by the roentgenograms proves the fact that the bone repair in the lased wound was superior to that of the control wound as well as macroscopically. Similar results have been given by LLLT in the HeNe laser for the alveolar socket following teeth extraction. These results certify that these laser beams stimulate the damaged bone tissue and activate its regeneration.

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Figure 1. Roentgenograms of the alveolar sockets following the simultaneous teeth extraction (4) and [4] in the female patient of 68 years old immediately after extraction (a) and a month after extraction (b). The alveolar socket of [4] was exposed to the 830 nm diode laser in every session of postoperative treatment but the wound of 4] had no laser therapy

Low Incident Energy Level Argon Ion Laser Therapy for Alveolar Bone Diseases

Extremely severe alveolar bone lesions caused by either periodontal alveolar osteitis or periapical alveolar osteitis have been usually difficult to cure by traditional methodology. Therefore these alveolar bone lesions are attractive indications for evaluating the therapeutic effects of lasers. The authors have already confirmed that the Nd:YAG laser therapy has a good therapeutic effect for these alveolar bone focuses. In this study the authors examined the therapeutic effect of the argon ion laser for alveolar diseases as low energy application.

Method. The argon ion laser was used in the multisynthetic wave mode for this laser therapy. Every wavelength of the argon ion laser of 457.9–514.5 nm were mixed in this laser system. The therapeutic techniques were as follows.

Endodontic laser therapy for periapical focus: The special optical fibre system designed for endodontic laser therapy, i.e. root canal laser treatment (RCFP) was applied for this laser therapy. The teflon cladding at the distal end of the RCFP was stripped off for a few cm, and the 0.6 mm diameter quartz fibre core was used as the laser-applying probe for the root canal. The proximal input end of the RCFP was connected to the distal end of the output fibre of the laser system using the authors' original fibre to fibre connector,⁸ and the laser beam could thus be delivered into a dental root canal through the

RCFP. This RCFP is very advantageous clinically because it is a disposable item and recleaving is very simple when the tip of the probe is broken.

Endodontic laser therapy has developed as follows: Following the complete widening of a dental root canal by a root canal reamer based on the conventional technique, the root canal laser probe of the RCFP was inserted into the dental root canal as deep as possible (Figure 2a). Thus the argon ion laser beam was shot to the widened canal towards the root apex. The laser probe was pulled up step by step towards the pulp chamber with repeating laser exposures in the root canal with an output power of 400 mW at the end of the probe, exposure time

Figure 2. The authors' laser therapy for apical alveolar foci. (a) Laser endodontic therapy using the authors' root canal laser probe. (b) direct laser surgery into the apical bone foci using a contact laser surgical probe

0.5 s, at a frequency of $0.5-1 \text{ s}^{-1}$ and thus a total exposure energy of the laser beam was 20–25 J. In addition to the endodontic laser therapy, the direct laser irradiation onto apical focus is tried on the larger focus site (Figure 2b).

Results. Argon ion laser therapy for apical alveolar bone foci: The argon laser therapy explained above was applied for periapical alveolar bone foci associated with chronic alveolar osteitis and extremely successful results have been obtained in almost all cases. Figure 3 shows a series of dental roentgenograms pre- and post-endodontic therapy for a severe apical alveolar bone focus associated with a chronic alveolar osteitis of the left lower first premolar ([4] in a 32-year old female patient. As shown in Figure 3a, the pre-treatment stage, large bone degeneration was observed in the apical alveolar bone of [4]. The patient had suffered from serious gingivitis and demonstrated percussive pain. The tooth was remarkably loose, associated with high mobility, and the patient could not chew any food with this tooth. Before application of the laser treatment, conventional endodontic therapy was continued for more than 2 months to treat the tooth without any good effect as seen in the roentgenogram in Figure 3b. The medial root canals were so highly degenerated that complete widening of them was difficult. The argon ion laser therapy was then applied to [4]. Fifteen days after the laser treatment, it was already observed that fine regenerative-like changes had begun in the bone degenerated focus as shown in Figure 3c. The subsequent roentgenographic follow-up showed that the bone focus had almost completely regenerated within 2 months following laser endodontic therapy as shown in Figure 3d, e, and the bone focus of [4] was completely regenerated within 4 months after the laser treatment despite the incomplete treatment of the medial root canal, as shown in Figure 3e. The severe alveolar bone focus was thus healed and the normal mastication ability of the tooth was completely restored.

No problems and no recurrence have been observed in the tooth for more than 2 years after the laser treatment.

Similar successful results to the above-mentioned example have been obtained in almost all other cases of chronic alveolar osteitis.

Discussion

The results of this clinical application of LLLT revealed the fact that LLLT has the bone regeneration activation effect as well as the high-powered Nd:YAG laser, which confirms that the bone regeneration effect of lasers is caused by the biostimulation of LLLT. Comparative observation of the results in the clinical application between low incident energy level argon laser and high power level Nd:YAG laser has proved that the former is superior to the latter in the bone regeneration effect. The difference of the bone regeneration effect between argon laser and Nd:YAG laser may be caused by the differences of absorption of the lasers in the bone focus depending on their wavelengths.

The authors designed the experimental study on examining the bone regeneration effect of lasers.

An artificial bone wound was formed on rat femur of rat model by drilling. In the lased group the bone wound was exposed to several kinds of laser beams separately immediately after the bone injury. The bone wound healing was followed up histologically and compared between the lased groups and the unlased group. As the result of this experiment the bone regeneration effect of lasers was certified histologically. Figure 4 shows the photomicrographs of the histological cross section of the femur including the drilled part of each group 10 days after the surgery ((a) control group, (b) Nd:YAG laser group). As evident from these results the bone regeneration in the group lased with Nd:YAG was superior to that of the unlased group from the viewpoints of active new spongy bone formation

Figure 3. Roentgenographical survey of the therapeutic effect in the severe chronic alveolar osteitis of the left lower first premolar ([4] to evaluate the bone regeneration effect of Ar^+ laser. (a) Pre-treatment, (b) 2 months following the conventional endodontic therapy, (c) 15 days after the Ar^+ laser endodontic therapy, (d) a month after the laser therapy, (e) 2 months after the laser therapy

Figure 4. Photomicrograms of the artificial bone wound in rat femur 10 days after the surgery. (a) Unlased control, (b) the bone wound exposed to 100 J/cm² of Nd:YAG laser just after the bone surgery

and the bone repair efficiency in the bone defect.

In addition to this, the author tried to approach the mechanism of the bone regeneration effect of lasers in the experiment of bone induction by bone morphogenetic protein (BMP). BMP is a bioactive substance which takes part in bone formation, and is one of the important factors in remodelling of bone tissue. BMP is initially produced by osteoblasts and stored in an inactive form in basal bone tissue. When bone formation is required, the BMP activates undifferentiated mesenchymal cells causing cytodifferentiation into osteoblasts leading to the production of bone tissue. The lased groups were superior to the control in bone formation by BMP. From the clinical and the experimental results, it is confirmed that the bone regeneration effect of lasers depends on the bioactivation following LLLT.

Conclusion

The authors' clinical application of lasers for alveolar bone lesions has confirmed that LLLT by the diode, HeNe and argon ion lasers have a bone regenerative effect. In particular the low incident energy level argon ion laser has more excellent effect on bone regeneration in apical alveolar foci than Nd:YAG laser. In addition to the clinical results, the authors'

experimental studies have certified the bone regeneration effect of LLLT.

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